COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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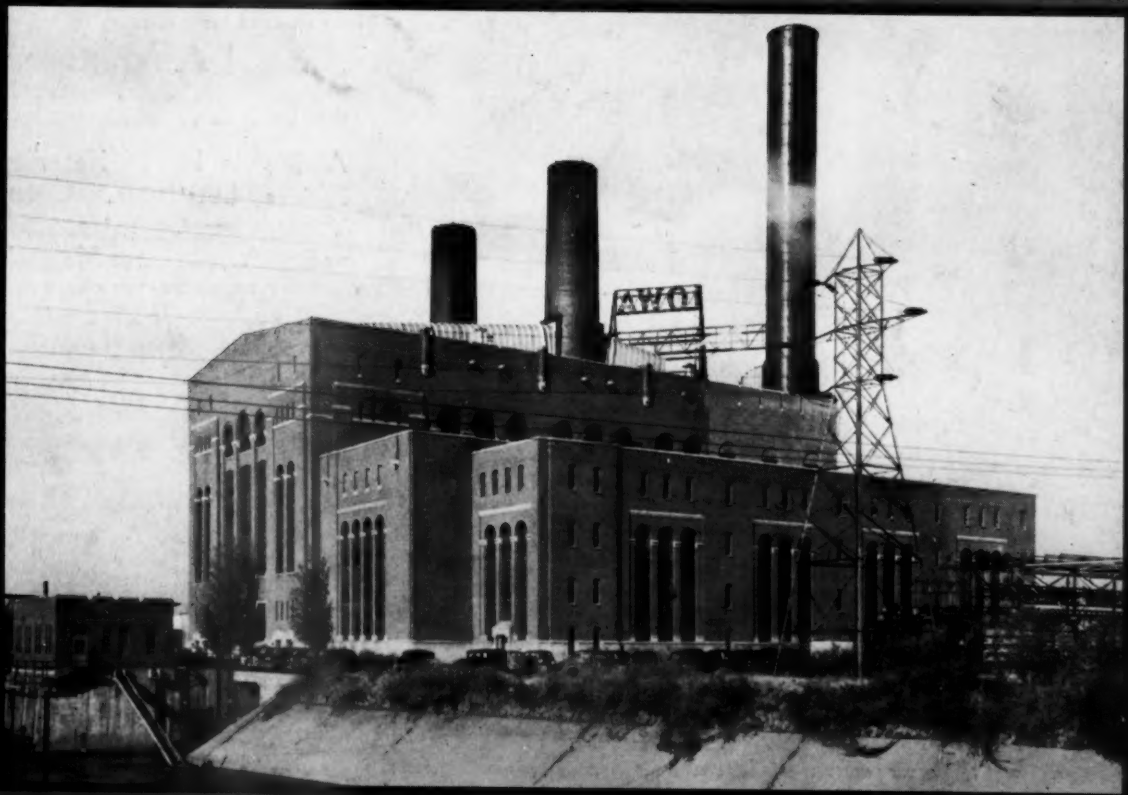

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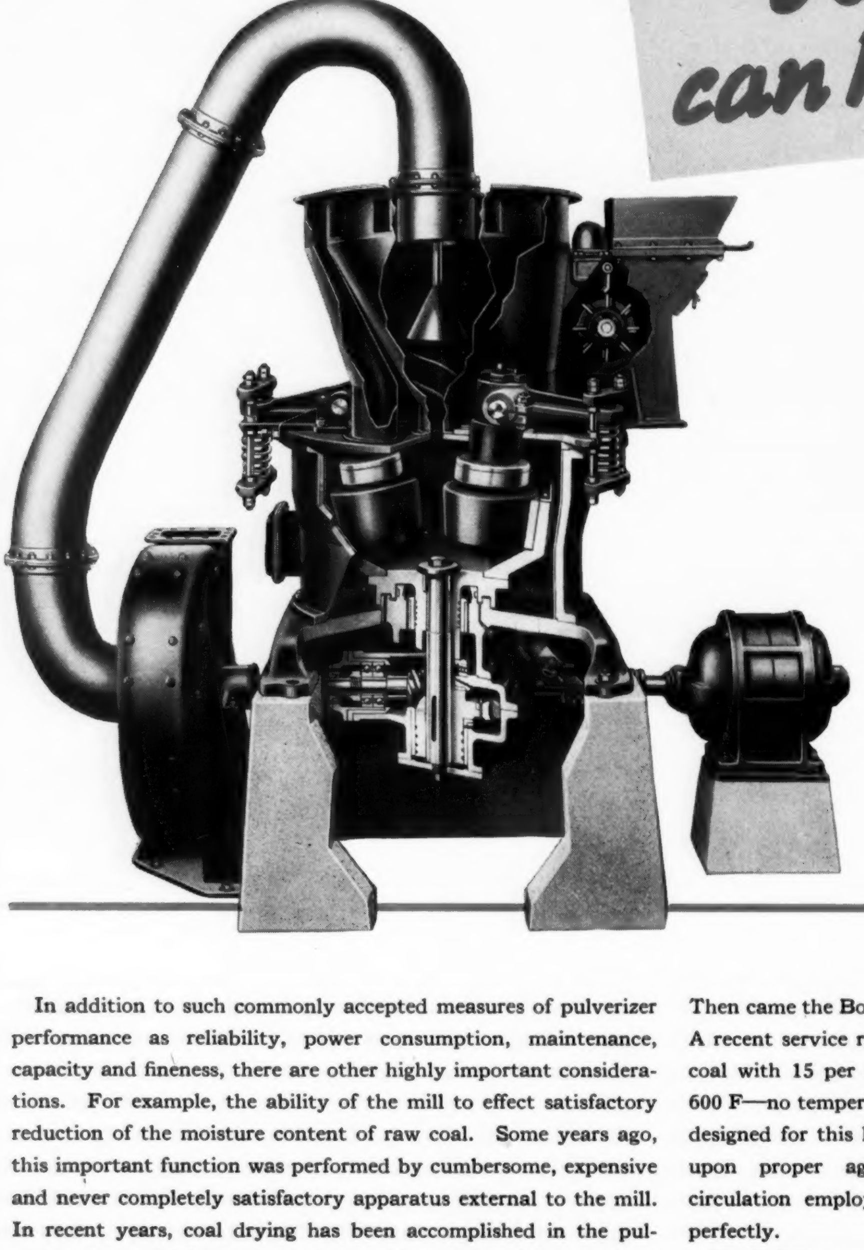

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TEN NUMBER SEVEN

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FOR JANUARY 1939

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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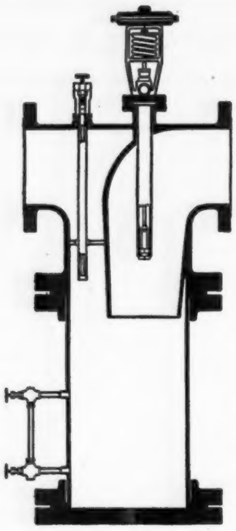

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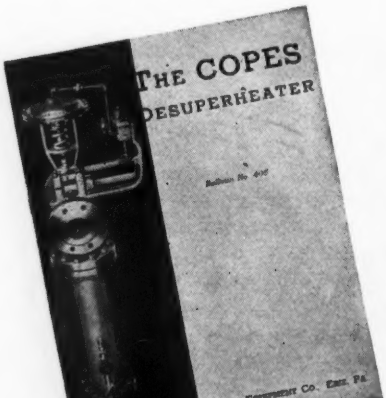

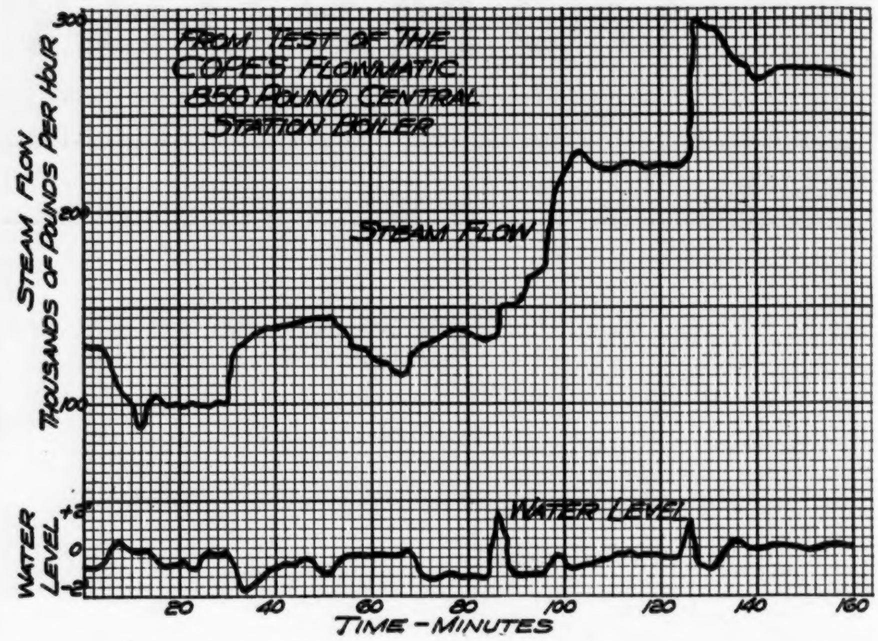

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EDITORIAL

Deductions from the Central-Station Statistics

Reference to the 1938 central-station statistics, appearing elsewhere in this issue, reveals a number of interesting facts, some of which should serve to disprove ill-founded opinions and others to indicate future needs of the industry.

The figures on construction expenditures show that less than one-third the total of 470 million dollars spent last year went into generating stations, whereas the greater part was for transmission, distribution and substation facilities. This will not be surprising to those conversant with the utility field, but it should be a revelation to those public-spirited or politically-minded individuals who have come to regard improved generating efficiency as a basis for reduction in electric rates.

It is significant, also, that water power provided 38 per cent of the total kilowatt-hours generated. This figure is in line with the percentages generated by hydro over the past eighteen years, which have varied by only two or three per cent during this period. It substantiates the fact that steam power remains the major source of electric energy production in this country, despite the publicity accorded water power in recent years.

While the total generating capacity was increased only 2.8 per cent, which is less than the normal yearly growth, it nevertheless represents nearly a million kilowatts of added capacity during a year when the total sales fell off six per cent. Within this total, however, the consumption by large commercial customers, which constituted nearly one-half of all the energy sold, fell off nearly eighteen per cent. This was offset to some extent by substantial increases in the residential, farm and electric railway demands. With industrial production resuming activity during the current year, as indicated by the index for some weeks past, this falling off in industrial load should not only recover but establish a new level exceeding that of 1937. This, added to the normal growth in the other classes mentioned, will probably absorb the capacity added during 1938 and point to the necessity for further increases in capacity which have been anticipated in the 1939 budget of 450 to 500 million dollars.

Obviously, only a part of the equipment included in the 1939 plans will be completed during the present year and much of this capacity will not be available until 1940. On the other hand, some of the 1938 projects are still in the construction stage and will go into service this year. On this basis, it is estimated that about 600,000 kilowatts will be added in 1939 and over a million kilowatts in 1940.

The kilowatt-hours generated per kilowatt of installed capacity was 3074 which represents an average capacity factor of about 35 per cent. However, this gives no clue to the reserve capacity for handling unanticipated demands, as the average load factor is not available. It should, nevertheless, serve to alleviate the fears of those who sense a power shortage in the event of a national emergency. The figures, of course, are averages for the whole industry and cannot be taken as a criterion for any particular locality.

Port Washington Still Leads in Performance

For the third consecutive year Port Washington Station, near Milwaukee, apparently holds the economy record among electric generating plants, with the net station heat rate for 1938 slightly under that of 1937. Had load conditions on the system been more favorable a figure considerably under 10,803 Btu per net kilowatt-hour would have been likely.

Of equal importance with the economy shown is the high availability factor and the total absence of outages, save those due to scheduled routine inspection and those occasioned by lack of load. Undoubtedly, the major credit for this enviable record attaches to conservative design plus competent operation.

Although this station has been operating for only three years its design dates back to 1931, construction having been held up during the early years of the depression. Since then, changing conditions in the field have been responsible for other installations of later date being designed along somewhat different and less conservative lines. With several, excellent performance is reported, although not quite up to that of Port Washington. Inasmuch as the majority of these have been topping installations, in which certain compromises had to be made to suit existing station conditions, it is not to be expected that they would attain the economy possible with a new high-pressure station operating on the straight condensing cycle. When operating records of stations of the latter type become available they will provide a basis for comparing 1931 and 1939 design practice.

The best performance reported to date for British power stations is that of Battersea with a net thermal efficiency of 27.63 per cent, corresponding to a station heat rate of 12,320 Btu per kilowatt-hour. It is possible that this may be found to have been bettered when the report for last year is published, and especially after the high-pressure extension to Battersea, which is now under construction, has been placed in operation. Each year the Electricity Commission reports on the performance of all the principal British power stations—a practice that might well be emulated in this country by the Edison Electric Institute or perhaps by the Federal Power Commission, both of which compile much power data.

PORT WASHINGTON'S Third Year of Outstanding Performance

During its third year of operation Port Washington Station averaged a net station heat consumption of 10,803 Btu per kwhr, which was about 1/2 per cent below the 1937 figure. The lowest monthly heat rate was 10,668 Btu per net kilowatt-hour. Available hydro power on the system was responsible for numerous week-end shutdowns and light morning loads with a resulting load factor of 64.9 per cent. The boiler and turbine-generator were out for routine inspection and maintenance for a week during the spring and the fall but no outages were chargeable to mechanical or chemical troubles during 1938. Turbine and boiler availability were on a par during this period. Complete operating records for the year are here given.

PERFORMANCE of the Port Washington Station of the Wisconsin Electric Power Company, formerly The Milwaukee Electric Railway and Light Company, because of its record as the world's most efficient steam-electric generating station, has been followed with unusual interest. An account of its second year's operation was given in the February 1938 issue of COMBUSTION and we are privileged, through the courtesy of the engineering department of the Wisconsin Electric Power Company, to report the third year's performance.

This plant, it will be recalled, is a single-boiler, single-turbine installation operating at 1300 lb per sq in. and 825 F total steam temperature, and employing the reheat cycle. The boiler, of the three-drum, C.E. bent-tube type, is rated at 690,000 lb of steam and the turbine-generator at 80,000 kw. Coal averaging 13,369 Btu per lb, as received, is burned in pulverized form in a dry-bottom furnace and a combination of convection- and radiant-type superheaters is employed.

There is little to report this year of operating experiences and troubles as the operation during 1938 was uneventful. The plant availability was 95 per cent when operating 91 per cent of the time.

The average station heat rate of 10,803 Btu per net kilowatt-hour (10,228 Btu gross) was slightly below the 10,835 Btu reported for 1937. For the three years during which the plant has been in regular service the average net station heat rate figures 10,864 Btu per

TABLE 1

OPERATING PERIODS AND REASONS FOR OUTAGES
1938

Period No.	Date		Hours Run	KWH Generated	Outage	
	Started	Finished			Hours	Reason
36*	Dec.27,1937*	Apr. 2,1938	2,328	126,640,000	29.0	Lack of load.
37	Apr. 4,1938	Apr.10,1938	139.20	6,703,000	28.93	Lack of load.
38	Apr.11,1938	Apr.16,1938	138.87	6,495,000	28.93	Lack of load.
39	Apr.18,1938	Apr.22,1938	115.03	5,409,000	220.87	General scheduled inspection.
40	May 2, 1938	May 7, 1938	139.10	6,652,000	28.87	Lack of load.
41	May 9, 1938	May 14,1938	139.05	6,567,000	29.05	Lack of load.
42	May 16,1938	May 21,1938	139.10	6,788,000	29.15	Lack of load.
43	May 23,1938	May 28,1938	138.82	6,470,000	52.77	Lack of load.
44	May 31,1938	June 4,1938	115.22	5,444,000	28.98	Lack of load.
45	June 6,1938	June 11,1938	137.02	6,573,000	31.05	Lack of load.
46	June 13,1938	June 18,1938	138.87	6,899,000	28.93	Lack of load.
47	June 20,1938	June 25,1938	139.13	7,330,000	29.05	Lack of load.
48	June 27,1938	Oct. 8,1938	2,468.37	125,976,000	218.87	General scheduled inspection.
49	Oct.17,1938	Dec.26,1938**	1,699.78	91,877,000	**	
Total			7,975.55	415,723,000	784.45	
Total	Nov.22,1935	Dec.26,1938	23,806.47	1,266,482,500	3,337.53	

See Mr. F. Dornbrook's A.S.M.E. paper in November, 1936, Mechanical Engineering for a detailed record of first 15 operating periods, and February , 1938, Combustion for information of subsequent 21 periods in 1936 and 1937.

*This operating period started October 10, 1937.

**Still in operation.

kwhr during which time the total output has been 1,266,482,500 kwhr. The lowest figure was attained for the month of August when the net heat consumption figured 10,668 Btu per kwhr. Lack of load at certain periods, due to power available from hydro connections on the system, reduced the early morning loads to around 20,000 kw and was responsible for a number of week-end outages; otherwise still better economy would have been possible. With a peak load of 82,000 kw and an average load for the year of 53,200 kw the annual load factor was 64.9 per cent. The average station water rate was 7.62 lb per kilowatt-hour and the amount of coal burned per kilowatt-hour, based on the averages of daily operating data as given in Table 5, was 0.83 lb.

TABLE 2

SUMMARY OF OUTPUT AND OUTAGE DATA

November 22, 1935 to December 26, 1938 (3.1 Years)

	Totals	Percents
Hours Elapsed	27,144	100
Plant Operated	23,806	87.7
Plant Outages		
General, scheduled inspections	1,575	5.8
Lack of load	820	3.0
Mechanical trouble	414	1.5
Corrosion trouble	529	1.9
Total	3,338	12.3
Plant Availability		90.7%
Output, KWH		1,266,482,500
Average load, KW		53,200
Peak load, KW		82,000
Load factor		64.9%

The accompanying chart shows the net Btu per kilowatt-hour plotted against the consecutive months of 1936, 1937 and 1938; also, a record of outages during this period. From this it will be noted that the average of the economy curve is continuously downward, whereas the outage plot is less broken and would have been solid had it not been for lack of load and scheduled inspections.

The continuous run of $5^3/_4$ months during the winter of 1937–1938 is significant. Had week-end load been available a longer run would have been made as the ensuing one-week outage for routine inspection and maintenance could readily have been deferred. All outages were scheduled, and consisted of one-week periods for spring and fall inspection and maintenance, in addition to which there were eleven week-end outages due to lack of load because of the hydro connections, previously mentioned.

Table 1 shows the operating periods, outputs and outages for 1938 and Table 2 gives a summary of the output, outages and availability for the three-year period. Monthly output and heat consumption data are given in Table 3. It will be noted that the October and November figures for heat consumption are the same. This resulted from averaging these two months' coal consumption to avoid possible error because of the coal bunker having been emptied during the October outage for routine inspection.

Turbine and boiler availabilities, as shown in Table 4, are running "neck-and-neck." The low-pressure turbine section was dismantled in April, after 10,000 hr of operation, in order to permit a thorough inspection, and the high-pressure section is scheduled to run 15,000 hr before being taken down for inspection in April or May 1939.

TABLE 3

MONTHLY OUTPUT AND HEAT CONSUMPTION DATA

Year	Month	Output, KWH Gross	Output, KWH Auxiliary	Output, KWH Net	Heat Consumption, Btu/KWH Gross	Heat Consumption, Btu/KWH Auxiliary	Heat Consumption, Btu/KWH Net
1935	October	3,353,000	431,600	2,921,400	14,215	2,100	16,365
	November	3,961,000	359,700	3,601,300	12,159	1,214	13,373
	December	33,853,000	1,969,000	31,884,000	10,962	677	11,639
	3 Months	41,167,000	2,760,300	38,406,700	11,342	815	12,157
1936	January	36,302,000	1,969,000	34,333,071	10,721	615	11,336
	February	35,938,000	1,914,502	34,023,498	10,655	600	11,255
	March	24,879,000	1,390,674	23,488,326	10,804	640	11,444
	April	32,333,000	1,795,342	30,537,658	10,339	607	10,946
	May	28,031,000	1,570,718	26,460,282	10,411	618	11,029
	June	28,033,000	1,513,510	26,519,490	10,373	592	10,965
	July	37,670,000	1,911,608	35,758,392	10,388	552	10,940
	August	41,189,000	2,061,043	39,127,957	10,314	543	10,857
	September	39,980,000	2,000,309	37,979,691	10,218	538	10,756
	October	29,386,000	1,584,682	27,801,318	10,135	556	10,691
	November	35,395,000	1,816,006	33,578,994	10,047	543	10,590
	December	35,089,000	1,833,459	33,255,541	10,282	567	10,849
	12 Months	404,165,000	21,301,782	382,863,218	10,376	578	10,954
1937	January	18,859,000	1,125,827	17,733,173	10,678	678	11,356
	February	37,489,000	1,926,968	35,562,032	10,398	563	10,961
	March	23,802,000	1,281,259	22,520,741	10,414	593	11,007
	April	26,580,000	1,442,464	25,137,536	10,353	594	10,947
	May	33,274,000	1,731,669	31,542,331	10,230	561	10,791
	June	35,166,000	1,770,473	33,395,527	10,132	537	10,669
	July	41,961,000	2,062,370	39,898,630	10,235	530	10,765
	August	42,938,000	2,099,808	40,838,192	10,275	528	10,803
	September	40,862,000	2,050,057	38,811,943	10,204	539	10,743
	October	28,122,000	1,515,084	26,606,916	10,292	586	10,878
	November	38,919,000	1,967,740	36,951,260	10,163	542	10,705
	December	40,973,000	2,106,791	38,866,209	10,225	554	10,779
	12 Months	408,995,000	21,080,510	387,914,490	10,277	558	10,835
1938	January	40,805,000	2,111,501	38,693,499	10,145	553	10,698
	February	38,483,000	2,134,234	36,348,766	10,320	605	10,925
	March	39,310,000	2,063,661	37,246,339	10,232	567	10,799
	April	26,649,000	1,496,639	25,152,361	10,420	620	11,040
	May	24,227,000	1,365,053	22,861,947	10,397	621	11,018
	June	28,496,000	1,554,651	26,941,349	10,292	593	10,885
	July	35,886,000	1,887,937	33,978,063	10,130	565	10,695
	August	38,227,000	1,960,836	36,266,164	10,121	547	10,668
	September	36,700,000	1,890,756	34,809,244	10,200	554	10,754
	October	27,706,000	1,476,339	26,229,661	10,155	565	10,720
	November	37,539,000	1,960,406	35,578,594	10,155	565	10,720
	December	41,715,000	2,103,687	39,611,313	10,173	540	10,712
	12 Months	415,723,000	22,005,700	393,717,300	10,228	575	10,803
1936-8	36 Months	1,228,883,000	64,387,992	1,164,495,008	10,294	570	10,864
1935-8	39 Months	1,270,050,000	67,148,292	1,202,901,708	10,323	577	10,900

Averages of daily operating data, covering fuel, the boiler and turbine rooms and auxiliary power are contained in Table 5.

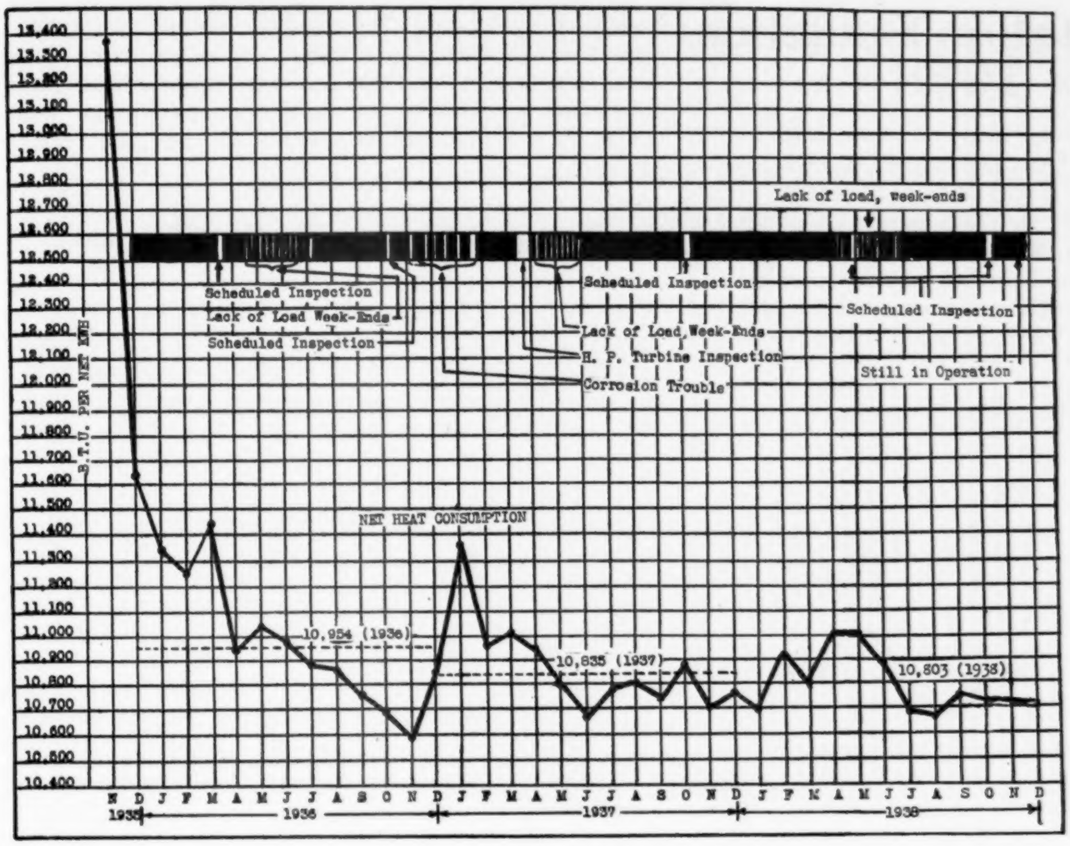
TABLE 4

USE AND AVAILABILITY DATA

Year / Equipment	1936 Boiler	1936 Turbine	1936 Plant	1937 Boiler	1937 Turbine	1937 Plant	1938 Boiler	1938 Turbine	1938 Plant	3-Year Average Boiler	3-Year Average Turbine	3-Year Average Plant
Annual Use Factor $\left(\frac{\text{Service Hours}}{\text{Annual Hours}}\right)$	86.2	85.8	85.8	84.4	84.3	84.3	91.1	91.0	91.0	87.5	87.3	87.3
Hourly Output-Capacity Factor $\left(\frac{\text{Ave. hourly output}}{\text{Rated hourly output}}\right)$	60.2	66.4	66.4	61.9	69.2	69.2	58.5	65.2	65.2	60.2	66.9	66.9
Annual Output-Capacity Factor $\left(\frac{\text{Annual Output}}{\text{Annual Rated Output}}\right)$	51.9	57.2	57.2	52.2	58.4	58.4	53.3	59.3	59.3	52.5	58.3	58.3
Annual Demand Factor $\left(\frac{\text{Demand hours}}{\text{Annual hours}}\right)$	95.8	96.8	96.8	91.3	93.7	97.1	91.6	94.2	95.4	92.9	94.9	96.4
Demand Availability Factor $\left(\frac{\text{Service hours}}{\text{Demand hours}}\right)$	89.9	88.9	88.9	92.4	90.0	86.8	99.4	96.7	95.4	93.9	91.9	90.4
Annual Availability Factor $\left(100 - \frac{\text{Repair hours}}{\text{Annual hours}}\right)$	91.1	98.1	89.8	93.1	89.9	86.5	98.8	96.2	95.0	94.3	94.7	90.4

TABLE 5 — AVERAGES OF DAILY OPERATING DATA

DATE, Month Ending	Jan 26	Feb 24	Mar 26	Apr 25	May 26	June 25	July 26	Aug 26	Sept 25	Oct 26	Nov 25	Dec 26	Annual Averages 1938	1937	1936	3-Year Ave 1936-8
COAL, TONS PER DAY																
1. To bunker	520	552	497	406	477	424	481	475	465	501	482	527	484	513	495	497
2. Pulverized	519	551	497	436	445	446	463	476	477	481	487	524	484	515	495	498
3. Burned, approx	518	550	499	443	437	446	463	477	477	481	487	524	484	515	496	498
4. Mill hours	32.02	34.47	30.82	25.49	25.87	27.29	27.68	28.75	28.45	29.15	28.79	33.01	29.24	32.29	33.79	31.77
5. Mill tons/hr	16.2	16.0	16.1	17.1	17.2	16.4	16.8	16.6	16.8	16.5	16.9	15.9	16.6	16.0	14.7	15.8
6. Mill system KWH per ton	14.9	15.5	15.6	14.4	14.3	15.0	14.5	14.7	14.8	14.2	13.8	15.1	14.7	14.6	15.8	15.0
7. Moisture, mill inlet, %	4.3	4.9	3.2	3.2	3.4	3.7	4.4	4.1	4.0	3.8	3.8	4.7	3.9	3.7	3.6	3.7
8. Moisture, mill outlet, %	1.7	2.0	1.8	1.7	1.8	1.7	1.5	1.7	1.6	1.5	1.5	1.6	1.7	1.7	1.8	1.7
9. No. 1 Mill Fineness % through																
200 mesh	64.15	64.64	64.70	62.42	59.42	65.55	68.10	66.77	65.59	67.48	69.18	69.18	65.59	65.28	65.14	65.33
100 mesh	89.04	88.53	88.07	86.82	84.52	88.02	89.58	89.04	88.13	89.05	90.64	90.93	88.53	88.78	89.21	88.84
48 mesh	98.26	98.03	97.79	97.28	96.33	97.72	98.29	98.31	97.88	98.00	98.62	98.78	97.94	97.86	97.97	97.92
28 mesh	99.82	99.80	99.76	99.69	99.47	99.75	99.84	99.85	99.78	99.78	99.88	99.90	99.78	99.74	99.76	99.76
20 mesh	99.97	99.97	99.97	99.96	99.93	99.97	99.98	99.98	99.98	99.98	99.98	99.98	99.97	99.96	99.95	99.96
10 mesh	100	100	100	100	100	100	100	100	100	100	100	100	100	99.99	99.99	99.99
10. No. 2 Mill Fineness % through																
200 mesh	63.64	60.43	64.12	64.21	65.58	66.84	67.16	69.19	68.32	67.58	69.37	70.24	66.39	65.06	66.55	66.00
100 mesh	87.99	85.14	87.98	88.14	88.72	89.26	89.19	90.34	90.07	89.88	90.41	90.88	88.99	88.58	90.13	89.23
48 mesh	97.61	95.50	97.55	97.57	97.84	98.09	98.13	98.49	98.38	98.39	98.35	98.63	97.96	97.78	98.39	98.04
28 mesh	99.73	99.50	99.73	99.70	99.76	99.81	99.80	99.89	99.85	99.85	99.83	99.86	99.77	99.73	99.81	99.77
20 mesh	99.97	99.92	99.97	99.96	99.97	99.88	99.96	99.98	99.98	99.99	99.97	99.98	99.96	99.96	99.97	99.96
10 mesh	100	99.99	100	100	100	100	100	100	100	100	100	100	100	99.99	99.99	99.99
Analyses																
11. Btu/lb, ash, moisture free	15012	14956	14820	14838	14816	15033	15060	15076	15090	15077	15104	15063	14996	14967	14939	14967
12. Btu/lb, dry	13538	13597	13387	13473	13450	13724	13703	13663	13676	13645	13675	13703	13603	13552	13606	13587
13. Btu/lb, as received	12875	12876	12908	12974	12925	13134	13040	13053	13047	13099	13142	13045	13011	12983	13035	13009
14. Moisture, %	4.9	5.3	3.6	3.7	3.9	4.3	4.8	4.5	4.6	4.0	3.9	4.8	4.4	4.2	4.3	4.3
15. Volatile, %	34.64	34.86	34.68	34.72	34.32	35.11	35.10	34.04	33.85	33.86	34.17	34.32	34.47	34.82	35.87	35.05
16. Fixed carbon, %	55.54	56.05	55.65	56.08	56.46	56.18	55.89	56.59	56.78	56.64	56.37	56.65	56.24	55.72	55.21	55.73
17. Ash, %	9.82	9.09	9.67	9.20	9.22	8.71	9.01	9.37	9.50	9.50	9.46	9.03	9.29	9.46	8.92	9.22
18. Sulphur, %	1.65	1.62	1.64	1.65	1.74	1.13	1.09	1.13	1.22	1.32	1.34	1.21	1.39	1.92	2.51	1.94
19. Ash fusion temperature, F	2255	2224	2220	2196	2212	2244	2305	2255	2368	2284	2268	2235	2256	2241	2199	2232
20. Pulverized Coal Composite Sample																
Btu/lb, ash, moisture free	14989	14901	14841	14842	14794	15018	15046	15077	15078	15090	15074	15050	14986	14945	14965	14965
Btu/lb, dry	13439	13491	13403	13449	13421	13665	13705	13648	13667	13679	13642	13653	13573	13506	13623	13567
Btu/lb, as received	13237	13248	13175	13232	13206	13446	13486	13443	13462	13487	13451	13476	13369	13299	13414	13361
Moisture, %	1.5	1.8	1.7	1.6	1.6	1.6	1.6	1.5	1.5	1.4	1.4	1.3	1.5	1.5	1.6	1.5
Volatile, %	33.87	34.58	35.56	33.89	34.27	34.65	34.98	34.09	34.39	33.26	34.06	33.78	34.28	34.43	35.80	34.84
Fixed carbon, %	55.79	55.96	54.75	56.72	56.45	56.34	56.11	56.43	56.19	57.39	56.44	56.94	56.29	55.95	55.23	55.82
Ash, %	10.34	9.46	9.69	9.38	9.28	9.01	8.91	9.48	9.42	9.35	9.50	9.28	9.43	9.62	8.97	9.34
Sulphur, %	1.71	1.55	1.47	1.67	1.42	1.23	1.13	1.19	1.23	1.30	1.39	1.29	1.39	1.86	2.51	1.92
BOILER ROOM																
21. Steam, million lb/day	10.178	10.631	9.842	8.716	8.607	8.808	9.252	9.581	9.543	9.765	9.632	10.349	9.576	9.924	9.733	9.744
22. Feedwater, million lb/day	9.935	10.464	9.722	8.651	8.494	8.744	9.096	9.344	9.283	9.491	9.498	10.156	9.407	9.601	9.556	9.588
23. Ave output, thd lb/hour	424	443	410	373	372	361	388	402	398	410	401	431	403	420	412	412
24. Hours steaming per day	24.00	24.00	24.00	23.38	23.12	23.14	23.83	24.00	24.00	23.81	24.00	24.00	23.78	23.62	23.65	23.68
25. Hours banked per day	0	0	0	0.20	0.35	0.38	0.07	0	0	0	0	0	0.16	0.16	0.22	0.18
26. % excess air	18	18	20	23	23	22	19	17	17	18	19	17	19	23	20	21
27. Pressure lb gage	1199	1267	1198	1191	1191	1190	1201	1201	1200	1228	1256	1268	1216	1190	1225	1210
28. Feedwater temperature, F	389	392	388	380	381	384	387	387	388	390	387	394	388	378	381	382
29. Feedwater pressure, lb gage	1328	1606	1336	1368	1363	1352	1355	1336	1341	1353	1430	1385	1379	1368	1421	1389
30. Feed pump efficiency, % actual	62.3	60.8	64.2	63.6	62.7	62.4	62.4	64.0	65.5	63.9	62.6	64.3	63.3	65.9	65.4	64.9
31. Feed pump efficiency, % stand	65.0	66.2	65.3	67.6	67.4	67.2	66.6	66.2	66.5	65.4	65.7	63.9	66.1	64.9	65.1	65.4
32. % combustible in fly ash	10.09	12.17	12.32	13.42	17.06	15.63	13.45	14.00	16.47	13.86	15.94	13.49	14.00	12.09	13.42	13.17
33. Exh to htrs, thd lb/day	0.3	0.2	0.3	6.5	6.4	5.2	0.9	0	0.1	0.6	0	0	1.7	2.6	15.2	6.5
Steam Temperature, F																
34. Radiant superheater outlet	681	682	681	687	693	688	688	686	687	690	694	691	687	673	675	678
35. Convection superheater outlet	843	842	843	840	839	841	842	842	842	842	842	843	842	839	831	837
36. Reheater inlet	538	535	539	535	533	536	538	539	539	537	537	538	537	538	534	536
37. Reheater outlet	843	842	844	839	837	840	842	843	843	841	842	841	842	840	831	838
Gas Temperatures, F																
38. Air heater inlet	729	741	734	717	721	721	723	722	716	728	728	741	726	741	734	734
39. Air heater outlet	366	372	373	362	355	361	363	367	364	363	361	371	365	375	378	373
40. Drop	363	379	361	355	366	360	360	355	352	365	367	370	361	366	356	361
Air Temperatures, F																
41. Air heater inlet	177	178	180	178	179	180	180	180	181	180	180	180	180	171	159	170
42. Air heater outlet	549	557	554	541	540	542	546	550	544	544	539	549	546	501	549	549
43. Forced draft fan inlet	111	118	115	113	117	120	123	123	122	120	115	112	117	118	115	117
44. Rise through air heater	438	445	441	429	423	422	423	426	422	424	426	437	429	433	434	432
45. % combustion air thru heater	93	93	98	93	97	96	95	94	94	97	97	95	95	95	93	94
46. Htr performance, % of std	106	106	104	107	110	108	108	106	107	108	107	104	107	101	97	102
TURBINE ROOM																
47. Average load, KW	54925	57439	52950	48185	47953	49372	50214	51605	51191	53030	52314	56375	52310	54865	52771	53262
Temperatures, F																
48. Throttle	836	835	835	834	831	832	833	835	835	833	835	837	835	831	825	830
49. 1st inlet	824	823	821	812	808	812	814	818	818	817	815	822	817	820	809	815
50. Reheater inlet	541	539	540	538	536	536	539	540	540	538	539	541	540	544	541	542
51. Reheater outlet	832	832	831	826	824	824	828	828	828	828	829	830	829	829	822	827
52. No. 3 heater	503	504	505	502	495	492	496	500	499	498	498	496	499	500	488	496
Pressures, lb gage																
53. Throttle	1168	1234	1165	1164	1163	1158	1169	1169	1168	1193	1227	1234	1184	1166	1184	1178
54. 1st inlet	1045	1093	1009	913	901	931	946	974	970	1004	968	1065	987	1035	986	1003
55. Reheater inlet	266	278	257	233	231	240	247	251	251	258	255	275	254	270	258	261
56. Reheater outlet	235	247	227	206	203	211	218	222	221	228	225	244	224	239	229	231
57. No. 3 heater	37.1	39.4	36.0	31.6	30.5	31.5	32.5	33.9	33.6	35.1	34.4	37.6	34.5	37.6	34.5	35.5
Stage Efficiencies, %																
58. 1st inlet to reheater inlet	81.2	81.2	81.1	79.5	79.5	80.0	80.3	80.6	80.6	81.0	80.3	81.4	80.6	80.2	77.9	79.6
59. Reheater outlet to No. 3 htr	84.6	84.0	84.0	84.2	84.9	85.2	84.9	84.4	84.3	84.4	84.6	84.6	84.5	84.3	85.4	84.7
60. Both sections	83.1	82.7	82.7	82.1	82.5	82.9	82.9	82.7	82.7	82.9	82.7	83.2	82.8	82.5	82.1	82.5
61. Circulating water outlet, F	39.0	39.3	40.2	45.2	50.2	53.2	60.8	61.6	67.5	60.0	47.7	40.8	50.5	49.8	50.8	50.4
62. Circulating water inlet, F	34.8	34.9	36.1	41.5	46.7	49.5	57.4	58.0	64.0	56.3	43.6	36.2	46.6	45.7	46.7	46.3
63. Circulating water rise, F	4.2	4.4	4.1	3.7	3.5	3.7	3.4	3.6	3.5	3.7	4.1	4.6	3.9	4.1	4.1	4.1
64. Condensate, F	47.4	49.7	39.6	53.0	56.5	59.4	66.8	67.6	73.2	66.0	53.7	47.0	57.5	57.5	58.5	57.8
Exhaust Pressure, in. Hg Abs																
65. Actual	.30	.31	.31	.38	.47	.52	.66	.69	.81	.65	.42	.34	.49	.49	.56	.51
66. Standard	.35	.36	.36	.42	.47	.52	.66	.69	.81	.65	.45	.37	.51	.51	.51	.51
67. High (+) or low (-)	.05	-.05	-.05	-.04	.00	.00	.00	.00	.00	.00	-.03	-.03	-.02	-.02	+.05	.00
68. Air pump inlet	.25	.26	.26	.32	.39	.47	.61	.64	.75	.58	.35	.25	.43	.46	.54	.48
69. Air leakage, cfm	2.9	3.2	3.3	4.2	6.1	5.2	4.3	3.1	3.1	3.3	3.3	2.7	3.7	3.6	3.1	3.5
ELECTRICAL																
70. Output, gross, 1000 KWH/day	1316.3	1374.4	1268.1	1110.3	1101.3	1139.9	1195.5	1233.1	1223.4	1257.7	1251.5	1345.7	1234.8	1301.9	1256.2	1264.3
71. Output, net, 1000 KWH/day	1248.2	1298.2	1201.5	1049.1	1041.1	1078.9	1132.7	1169.9	1160.3	1193.2	1186.1	1277.8	1169.8	1235.4	1190.8	1198.7
72. Auxiliaries, 1000 KWH/day	68.1	76.2	66.6	61.2	60.2	61.0	62.8	63.2	63.1	64.5	65.4	67.9	65.0	66.5	65.4	65.6
73. Auxiliaries, %	5.2	5.6	5.3	5.5	5.5	5.4	5.2	5.1	5.2	5.1	5.2	5.0	5.3	5.1	5.2	5.2
74. % for coal preparation	.59	.62	.61	.57	.58	.59	.53	.57	.56	.55	.54	.59	.57	.56	.62	.59
75. % for boiler room fans	1.03	1.05	1.08	1.08	1.03	1.07	1.02	1.00	1.00	1.02	1.01	.99	1.03	1.06	.98	1.02
76. % for boiler feed pumps	1.54	1.98	1.52	1.56	1.58	1.54	1.58	1.52	1.49	1.54	1.65	1.55	1.58	1.48	1.57	1.54
77. % for circulating pumps	1.09	1.05	1.14	1.25	1.27	1.21	1.20	1.16	1.18	1.15	1.16	1.07	1.16	1.09	1.15	1.13
78. % for miscellaneous	.95	.96	.95	1.04	1.04	.99	.87	.85	.95	.84	.84	.80	.96	.89	.90	.92
79. Station water rate, lb/KWH	7.56	7.61	7.67	7.79	7.71	7.67	7.61	7.58	7.59	7.56	7.59	7.55	7.62	7.53	7.61	7.58
Station Heat Consumption Btu per KWH																
Gross	10145	10520	10828	10420	10397	10298	10130	10121	10200	10155	10155	10172	10228	10277	10376	10294
Auxiliaries	553	605	567	620	621	595	563	547	554	565	565	540	575	558	578	570
Net	10698	10925	10799	11040	11018	10885	10695	10668	10754	10720	10720	10712	10803	10835	10954	10864

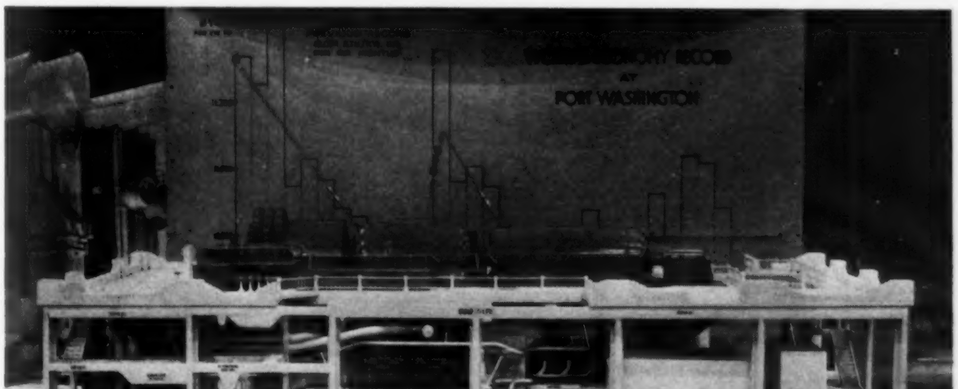


Graph of station heat consumption and outage record over three-year period.

Nearly two years of trouble-free operation have now passed since corrosion in the furnace-bottom screen tubes[1] was experienced for a month following the first year of service. The most recent hydrogen-in-steam measurements show approximately one ounce per day iron loss in the total boiler unit, including the superheaters. For the past sixteen months the boiler-water alkalinity has averaged the low value of 5 ppm, corresponding to a pH of about 9.6. The turbine blading is reported as scrupulously clean and all possibilities of caustic embrittlement have apparently been eliminated by the absence of caustic soda in the boiler water.

The illustration below is reproduced from a photograph of a scale model of the Port Washington turbine-generator and condensing equipment which formed a part of the Allis-Chalmers exhibit at the recent Power Show in New York. It will be noted that a chart of performance forms the background.

[1] This corrosion experience and the means employed to overcome it were discussed at length by M. K. Drewry in COMBUSTION of February 1938.



Model of Port Washington turbine-generator and condensing equipment exhibited at New York Power Show.

Central-Station Statistics for 1938

Figures compiled by the Edison Electric Institute for the year just ended, based on actual reports for ten months and estimates for the two last months, give a comprehensive summary for the central station industry covering the supply and disposal of electrical energy, the generating capacity, number of customers, revenues and expenditures and a breakdown of sales among different classes of customers. The following figures are excerpts from this report:

SOURCE AND DISPOSAL OF ENERGY

	1938	1937	Per Cent
Source of Energy			
Generation			
By fuel burning plants......	67,600,000,000	74,206,276,000	−8.9
By water power (hydro)....	41,400,000,000	40,959,360,000	+1.1
Total generation.........	109,000,000,000	115,165,636,000	−5.4
Net purchased energy........	4,850,000,000	4,644,712,000	+4.4
Total net input..........	113,850,000,000	119,810,348,000	−5.0
Disposal of Energy			
Total sales to ultimate customers....................	93,400,000,000	99,446,364,000	−6.1
Company use................	2,650,000,000	2,322,903,000	+14.1
Losses and unaccounted for...	17,800,000,000	18,041,081,000	−1.3
Total net output.........	113,850,000,000	119,810,348,000	−5.0

KILOWATT GENERATING CAPACITY ON DECEMBER 31st

	1938	1937	Per Cent
Type of Prime Mover			
Steam turbines and engines.	25,600,000	24,637,926	+3.9
Water wheels and turbines...	9,700,000	9,634,014	+0.2
Internal-combustion engines.	700,000	688,381	+1.7
Total generating capacity (kw)..................	36,000,000	34,960,321	+2.8

The total number of customers is given as 27,765,480 which represents a 2.2 per cent increase over 1937; whereas the 93,400,000,000 kwhr sold was 6.1 per cent less than that of the preceding year. The total revenue of $2,172,750,000 was 0.4 per cent under that of 1937. It is significant that over 47 per cent of the energy sold was to customers in the large commercial class, including manufacturing plants, although the revenue from this class was only approximately 25 per cent of the total. Moreover, the sales to these customers was 17.7 per cent less than in 1937 and the revenue 11.8 per cent less, which reflects the falling off in industrial activity during the past year. On the other hand, both the farm and the residential loads and revenue showed an increase with the residential kilowatt-hours per customer amounting to 850. The average revenue per kilowatt-hour, considering all classes, was $2^1/_3$ cents.

Another interesting tabulation shows the relation of kilowatt-hours generated to installed capacity which was as follows:

RELATION OF KWHR GENERATED AND KW CAPACITY

	1938	1937	Per Cent
Kilowatts generated (year)....	109,000,000,000	115,165,636,000	−5.4
Kilowatt generating capacity (Dec. 31st)................	35,950,000	34,960,321	+2.8
Kilowatt generating capacity (average)................	35,455,000	34,610,200	+2.4
Kwhr Generated per Kw of Capacity			
Based on kw as of December 31st....................	3,032	3,294	−8.0
Based on average kw for year	3,074	3,328	−7.6

Construction expenditures amounted to 470 million dollars which was only 10 million under 1937 and 180 million over 1936. Of this amount, 130 million dollars went into steam stations, 20 million into hydro plants, 50 million into substations, 240 million into transmission and distribution and the remaining 30 million for miscellaneous electric expenditures. The estimated construction budget for 1939, based on returns from questionnaires sent out to the various companies and compiled by the Institute, is between 450 and 500 million dollars.

Westport Station To Be "Topped"

The Consolidated Gas, Electric Light and Power Company of Baltimore has recently let contracts for equipment to top a portion of its Westport Station. The installation will consist of two Combustion Engineering high-pressure boilers of the three-drum bent-tube type supplying steam at 1325 lb, 915 F, at the superheater outlet, to a 25,000-kw G.E. turbine-generator exhausting to the present 200-lb turbines. An extension to the present building will house the new equipment.

The new steam generating units will be designed for a maximum rating of 313,000 lb of steam per hour, with feedwater at 330 F, or 330,000 lb with feedwater at 383 F. Each unit will be fired by four Type R horizontal turbulent burners receiving pulverized coal, through independent feeders, from two CE-Raymond bowl mills. The furnaces will be completely water cooled and have bottoms of the V-shaped dry type. Continuous, fin-tube economizers and Ljungstrom air preheaters will be employed.

Fly Ash in Cinder Concrete

Attention has been called to an omission in the report of the A. S. M. E. Annual Meeting, in the December issue of COMBUSTION, in connection with the abstract of the paper by Messrs. Thorson and Nelles on the utilization of pulverized coal ash, which is likely to be misleading and prove detrimental to the cause of fly ash. In discussing the use of fly ash as fine aggregate in cinder concrete the abstract reads:

"As a fine aggregate in cinder concrete the fly ash improves the workability and increases the strength. Also, because of its light weight such concrete is highly desirable for steel and concrete buildings. However, it has been prohibited by building codes because its porosity permits the water to attack the steel."

The original text was as follows:

"Cinder concrete, because of its light weight, is highly desirable for use in steel and concrete buildings, but has been prohibited by building codes because its porosity enables water to attack the steel. The *use of fly ash* in the mix reduces porosity and *removes* this objection by code authorities."

Opposes St. Lawrence Project

The Coal Division of the American Mining Congress which met in Pittsburgh in December went on record as opposed to the pending treaty with Canada for the building of a Great Lakes-St. Lawrence waterway. This opposition is based on the contention that the proposed hydro development would displace millions of tons of coal and thus throw many miners out of work, as well as railroad workers and would also open the way for the importation of foreign coal from Black Sea ports to the Middle West.

INDUSTRIAL POWER

By C. W. E. CLARKE

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Brief reference to this paper was contained in the report of the recent Annual Meeting of the A. S. M. E. which appeared in the December issue of COMBUSTION. Because of the many aspects of industrial power with which the author deals in considerable detail, a more extensive abstract is here presented. Among the subjects discussed are steam cycles adapted to industrial power plants, together with examples of each, types of turbine-generators employed, steam-generating equipment, fuels and their utilization, boiler feedwater treatment and evaporators. The economic aspects of industrial power engineering are also stressed.

THE art of providing suitable electric-generating facilities for industrial use requires analysis of many factors such as type of load, source of water and fuel supply, condition of existing equipment, future growth, possible steam pressures and temperatures, interconnections, and numerous other items incident to any particular project.

As a general premise it is safe to say that in industrial plants where there is a reasonable demand for process steam of moderately low pressure, it will generally be found economical to furnish generating capacity up to the requirements for this steam, and in cases where no process-steam requirements exist it will usually not be found economical to install condensing units.

First let us consider cooperation between manufacturing plants and public utility companies in generating steam and electricity. In most localities the manufacturing industry and the utility have many interests in common. There are, for example, by-products such as waste heat, coke, wood waste, coke-oven gas, blast-furnace gas and oil-refinery refuse. In the interests of the community, as well as for conservation of resources, these products should be used. Production of steam and power is one important means of doing so. Yet in many plants using steam for process the demand for steam does not synchronize with the demand for electric energy. Seasonal demands also complicate the picture. When a tie line to the utility is available, the latter's resources of power can take care of fluctuations in demand. No condensing machines need be installed as the high-pressure turbines run exclusively for low-pressure-steam requirements. Spare equipment with its costly fixed charges can be omitted and when the turbine is out the utility supplies the electric load and the boiler the steam requirements, through reducing valves.

Power companies are now meeting this important economic problem, which frequently involves both the sale of electric energy to and its purchase from the same industrial customer. Progress along this line has been slow but is certain to accelerate in the future as the demand for cheaper industrial power becomes more determined.

Turbine-Generators

Due to the great variety of conditions to be met in industrial practice, turbines for such applications are usually built to order, and the following types are available for both condensing and non-condensing service: non-extraction, single automatic extraction, double automatic extraction, and mixed pressure. These turbines can be built for any reasonable capacity and steam conditions and a wide choice of extraction and exhaust pressure is available. Except for special cases, they usually operate at 3600 rpm.

Although maximum steam conditions up to about 1300 lb and 950 F can often be justified, from the practical viewpoint 900 lb pressure and 850 F total temperature appear to be the sensible limits for most industrial plants. In a few cases, such as at the River Rouge Plant of Ford Motor Company, installations have been made at 1215 lb and 925 F. Incidentally, there is in the process of construction an installation which is to use 2500 lb pressure. Usually such plants approach the utility stations in size of units and skilled personnel to supervise operation. The ordinary industrial plant is not so fortunate.

As many industrial plants now operate at about 200 lb pressure, the 650-lb superposed turbine offers substantial returns on the investment and, moreover, utilizes medium pressures and temperatures. Generally speaking, industrial-plant conditions do not lend themselves to the straight superposed unit as readily as do those existing in central stations. Variations of the superposed turbine, permitting steam extraction for process use, are becoming widely used in industry as discussed later under "Steam Cycles."

Ordinarily, the requisite pressures of process steam and the use made of it determine the most desirable conditions for the throttle steam. Usually a small amount of superheat in the process lines is desirable to insure dry saturated steam at the point of use. To satisfy these conditions it is seldom necessary to exceed 600 lb pressure and 800 F at the turbine inlet.

TABLE 1—EFFECT OF SIZE OF STEAM-GENERATING EQUIPMENT ON PRICE

Size of steam-generating equipment, lb per hr	Cost per 1000 lb of steam, per cent
100,000	Base
200,000	0.700
300,000	0.600
400,000	0.550
500,000	0.525
750,000	0.500
1,000,000	0.485

In too many new installations the block of additional power required is underestimated; consequently, the capacity of the new unit soon becomes inadequate. Future growth of electric load is a problem that deserves thorough study and analysis. Moreover, the greater the machine capacity, the less the unit initial cost and maintenance. In Table 1 are some recently published figures showing the influence of size on the cost per 1000 lb of steam for steam-generating equipment. Similarly, Table 2 indicates the effect of size on the price per kilowatt of turbine-generators. The figures are for 450-lb 750-F units, but the ratios will be approximately the same for other pressures.

TABLE 2—EFFECT OF SIZE OF TURBINE-GENERATORS ON PRICE

Rating, kw	Cost per kilowatt, per cent
1000	Base
1500	0.850
2000	0.775
2500	0.730
5000	0.635
7500	0.625
10,000	0.687
15,000	0.652
25,000	0.623
50,000	0.462

Encouraging this trend toward larger units has been the increase in availability of boilers. It is practically equal to that of turbine-generators. Hence, the common practice today of installing one boiler unit per turbine unit on interconnected systems or in plants having two or more units.

Steam Cycles

Conditions existing in each industrial plant dictate the steam cycle and type of turbine to be selected.

STEAM CYCLE No. 1. The simple cycle shown in Fig. 1 offers large savings when applied to an existing power plant. The back-pressure turbine, with throttle pressure higher than the existing plant equipment, exhausts the steam into the old generating equipment or to the station steam header. A few of the industrial plants which recently have adopted this cycle are described below.

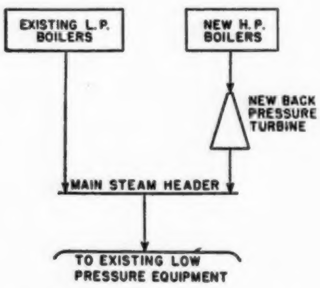


Fig. 1—Steam Cycle No. 1

Weirton Steel Company at Weirton, W. Va., was faced with a rapidly increasing power load. There was no spare generating equipment and the 215-lb boiler plant was 26 years old. They installed a 10,000-kw superposed machine operating at 800 lb throttle pressure and 800 F total temperature. This unit exhausts at 215 lb back pressure and delivers sufficient steam to permit retirement of all the old low-pressure boilers. The result has been continuous and satisfactory operation with a saving of 500 tons of coal per day for the same load carried previous to the expansion. The two boilers, each with a capacity of 400,000 lb per hr, are fired primarily with pulverized coal, with coke-oven gas automatically spilled over into the furnaces when not needed in the steel mill. The boilers operate on 100 per cent makeup water, chemically treated.

The recent installation at the Dow Chemical Company is another example. The old plant consisted of several 400-lb 600-F boilers and turbines. Part of the 400-lb steam is used directly in the chemical processes and the remainder passes through reducing turbines, some exhausting at 150 lb pressure, some at 10 lb pressure, and the others expanding to 26 in. of vacuum, where the steam is exhausted to evaporators. Instead of enlarging the 400-lb plant it was decided to purchase a 1250-lb 825-F boiler and back-pressure turbine.

Modernization of the Gulf Refining Company's power plant at Port Arthur, Texas, is another typical example. In 1917 the power facilities were designed for 200 lb and 530 F with 15 lb exhaust to process. Six years later another plant was built for 240 lb and 580 F, and two 5000-kw condensing machines. In 1928 another 5000-kw condensing turbine-generator was purchased for a throttle pressure of 15 lb to use excess steam not required in process work. A year later they installed a 10,000-kw 500-lb 630-F turbine, exhausting to process at 130 lb. Although these combined plants were generating a kilowatt-hour at a very low heat consumption, plans were made in 1937 to reduce this still further through increasing by-product generation. Six 225-lb boilers in use since 1917 were replaced with two modern oil-fired or gas-fired self-contained steam generators with capacities of 200,000 lb per hr at 725 lb and 650 F. Two new 650-lb 650-F steam turbines were installed to drive the existing 4000-kw generators. These turbines exhaust to process at 130 lb and 400 F. In case the turbines fail to maintain steam pressure in the process lines, three sets of pressure-reducing and desuperheating apparatus automatically make up any deficiency.

A novel use of the back-pressure turbine occurs in one of America's leading plants devoted to the manufacture of rubber products. Due to a high percentage of impurities in the raw feedwater it was decided to use a closed circuit in the feed cycle. The 10,000-kw machine operates on a throttle pressure of 1250 lb and at a steam temperature of 750 F, and exhausts at 235 lb to evaporators which in turn supply steam to process at 180 lb pressure. Thus, the boiler-water problem is simplified and makeup practically eliminated. The evaporator feedwater is treated chemically in order to prevent hard scale deposits in the evaporator. In this case the cost of power is being materially reduced as compared with that from a complete condensing system, and the cost of the vapor leaving the evaporators compares favorably with that of process steam from the old low-pressure boilers. On the basis of normal-load operation the investment in the entire installation will be returned in $3^1/_2$ to 4 years.

Designed to handle base load, the boiler and turbine-generator have been available 95 per cent of the time during the last year. The unit is shut down each week-end for a period of 24 to 36 hours. During this time the high-pressure boiler is bottled up and retains a pressure between 200 and 500 lb. After operating $2^1/_2$ years, the turbine was opened for inspection. It was found to be in good condition and free from deposits on the blading.

Steam Cycle No. 2. This cycle is illustrated in Fig. 2 and consists of a turbine with throttle pressure higher than that of the existing plant, bled at one point only and exhausting into the old generating equipment or station header. It is ideal where the power-generating facilities already include condensing turbines. There

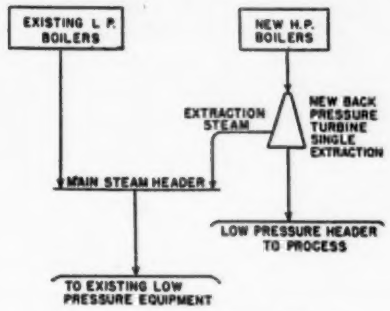


Fig. 2—Steam Cycle No. 2

are several industries which employ two pressures for steam process use, such as the kraft paper trade, for example, where this cycle is quite generally employed. The turbine-governing system is designed to maintain constant pressures at the extraction point and at the exhaust, with demands for steam varying independently.

The power facilities at Gaylord Container Corporation in Louisiana were modernized by the installation of equipment operating on this cycle. A 450-lb 710-F boiler unit and a 7500-kw back-pressure automatic-extraction turbine were used in conjunction with the old 9000-kw plant of three condensing machines. The investment of approximately $400,000 produced savings in operating costs of $650 per day.

Similarly, in the food industry, General Foods Corporation at Battle Creek, Mich., recently invested about $500,000 in power-plant improvements and are obtaining annual operating savings of $100,000. Prior to 1937 all power was purchased and the five boilers operating at 150 lb pressure supplied the steam for cooking. This boiler plant is now standby equipment to one 100,000-lb-per-hr 625-lb 720-F steam generator supplying a 2500-kw 30-lb back-pressure, 125-lb extraction-type turbine. All electric energy needed beyond that generated by process steam is purchased from the local utility. One unusual feature which is used to provide additional flexibility is a surface condenser operated only during the summer time when there is no heating.

Steam Cycle No. 3. The double-extraction condensing turbine used in steam Cycle No. 3, shown in Fig. 3, involves a more complicated control for maintaining constant-extraction pressures but it has the advantage of greater flexibility through using a condenser to balance the power demand. It is popular for new plants and has the same effect as applying Cycle No. 2 to old condensing plants. The necessity for controlling the extraction pressures and passing excess steam to the condenser requires throttling or bypassing of steam for all electric and steam loads except the one combination for which the machine has been designed. The farther the actual operating conditions depart from the design conditions the lower will be the turbine efficiency. However, a number of turbines of this type are in successful operation and have been very satisfactory, especially where the load has been fairly steady and predictable within reasonable limits. In any case it should be used where there is danger of serious lack of balance between steam or electric loads which would cause loss of economy.

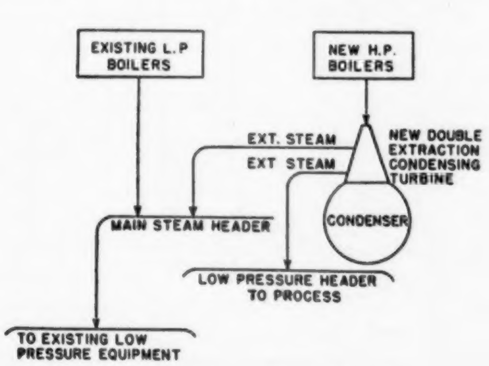


Fig. 3—Steam Cycle No. 3

Recently the R.C.A. Manufacturing Company, Inc., modernized its power plant by installing two new double-extraction condensing turbines to drive old 2500-kw generators. The two new boilers and the turbines are designed for steam at 900 lb pressure and 750 F. The 175-lb extracted steam enters the station headers to operate old low-pressure turbine-generators. The 20-lb extraction opening supplies steam to process. The total cost of this reconstruction work was about $750,000 and the annual savings in the fuel bill and maintenance charges amounted to approximately $125,000.

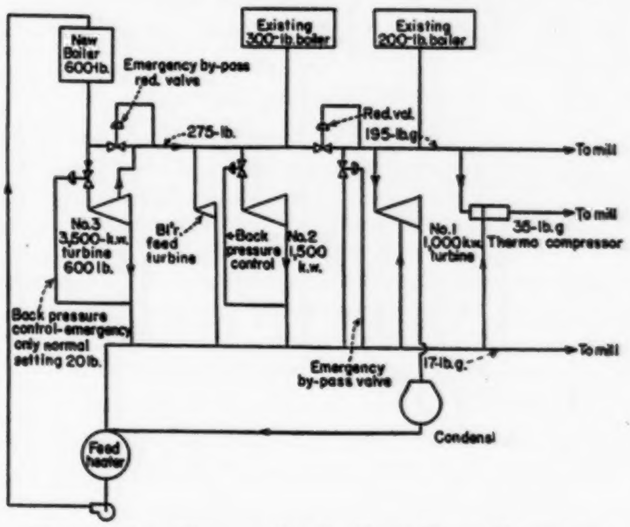


Fig. 4—Flow Diagram for the Scott Paper Company

Mixed-Pressure Turbines

The mixed-pressure turbine is provided with an opening which receives excess steam from process passing it through the lower pressure stages, or should the requirements be reversed, steam is extracted to process. There are a number of special cases where such a turbine can be used to advantage, one of which is the forging plants of the automobile industry. Most automobile plants are located where purchased power is available at attractive rates. Moreover, their steam requirements are generally met by low-pressure boilers without electric generation or with only sufficient power generation to balance the need for steam. The drop-hammers, using 125-lb to 175-lb steam, exhaust near atmospheric pressure to process, such as heating in winter, hot-water heating,

drying ovens and pickling tanks. Sometimes the use of motor-driven and steam-driven compressors gives control over this low-pressure steam to avoid waste to atmosphere. With these conditions in mind it becomes apparent that a combination extraction and mixed-pressure condensing turbine is an ideal method of controlling the process-steam supply and generating some cheap power.

An ingenious arrangement of back-pressure, back-pressure-extraction, and mixed-pressure-condensing types of turbines is shown in Fig. 4, which is a line diagram of the power-generating facilities at Scott Paper Company, Chester, Pa. This plant operates 24 hr a day and prior to the installation of the new boiler and 3500-kw turbine-generator, about two-thirds of the power requirements were purchased. As the system is now operated, No. 2 turbine governs the back pressure; therefore, the power output depends on this 17-lb-steam demand. If this load falls below the control of No. 2 turbine, the emergency governor on No. 3 turbine, set at 20 lb, goes into action, automatically reduces load and, in turn, also the steam output of No. 3 turbine. All 17-lb steam in excess of normal process demands is absorbed by No. 1 turbine, running as a mixed-pressure machine either on 200-lb or 17-lb steam, or both.

Steam-Generating Equipment

The modern steam generator bears little resemblance to the old-time boiler which was largely a vessel filled with water. To take its place have come elaborate designs of water walls, economizers, air preheaters, superheaters, and in some cases reheaters. Lack of water storage is compensated for by high steaming ability fortified by quick-acting feedwater regulating equipment and automatic combustion-control systems. All of these factors have helped to produce the present boiler unit with its very flat efficiency curve.

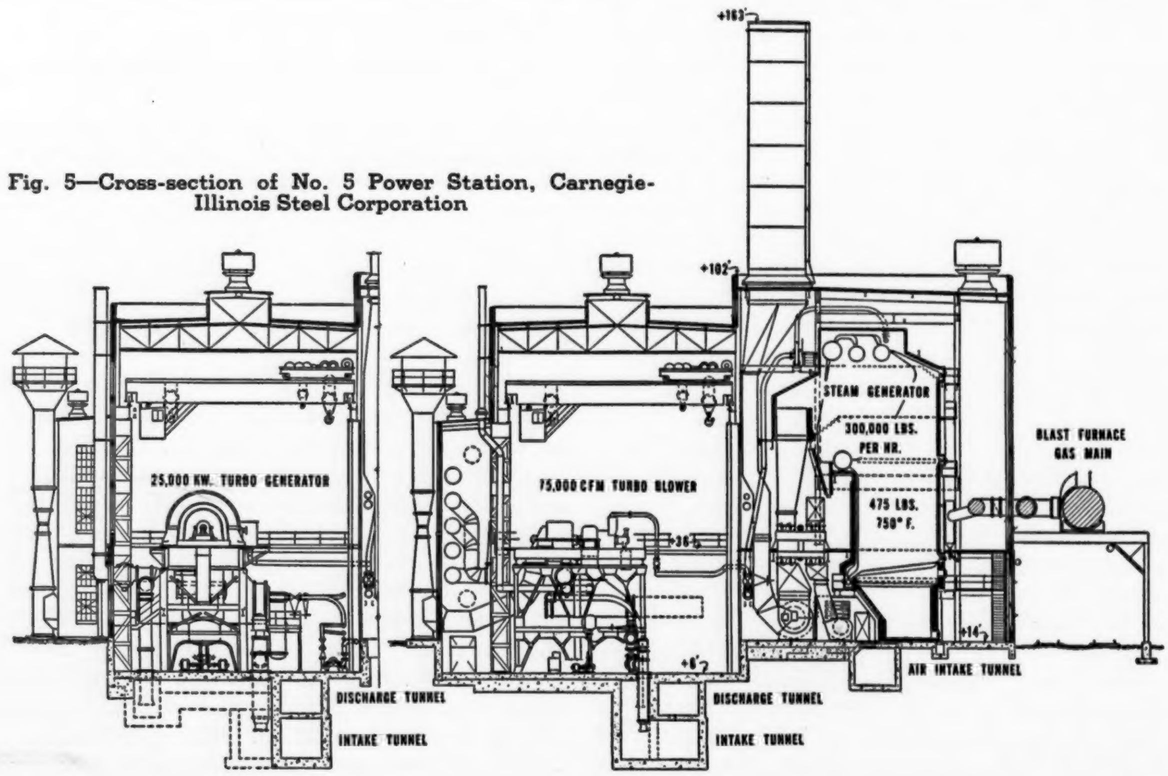
Local conditions affect the method of firing. The character of the coal and the size of the unit are determining factors as to whether stokers or pulverized fuel shall be selected, and if the latter, whether the wet- or dry-bottom furnace shall be adopted. In some localities, natural gas and oil are cheap and abundant. Steel-mill practice dictates that excess blast-furnace or coke-oven gas receive priority over other fuels. Some boilers are arranged for three or four different fuels which come into service automatically according to some predetermined sequence. In general, where a multiplicity of fuels is to be used, pulverized-fuel firing is, for the solid fuels, the easiest method of accomplishing desired results. It is necessary that all fuels be burned in the same furnace to avoid the expense of duplicate equipment.

In the case of industrial plants using steam for process work, while the average quantity of steam rejected by the generation of electrical load may balance the average requirements of industrial steam, the times at which these loads balance are apt to be seriously out of proportion and unless a careful analysis is made the use of averages in determining these factors will be misleading.

One of the largest industrial power plants recently completed is the No. 5 Power Station of the Carnegie-Illinois Steel Corporation at its South Works in Chicago. Fig. 5 shows a cross-section of this plant which was placed in service last winter. The building houses three steam-generating units, each with a capacity of 300,000 lb of steam per hr at 450 lb pressure and 750 F temperature, one 25,000-kw condensing turbine-generator and three 75,000-cfm condensing turbine-blowers. Space is also provided in the present building for one additional boiler, a future 50,000-kw turbine-generator and another turbine-blower.

The boilers are of the four-drum bent-tube design equipped with convection-type superheaters, econo-

Fig. 5—Cross-section of No. 5 Power Station, Carnegie-Illinois Steel Corporation



mizers and air preheaters. Each has two induced-draft fans and two forced-draft fans. A geared turbine drives one of each type of fan and a two-speed motor drives the other.

About 20 per cent of the total feedwater supply is makeup taken from Lake Michigan and treated by a hot-process lime-and-soda softener. A deaerating heater and two closed feedwater heaters complete the feedwater-heating equipment.

An interesting feature of these units is the tangential firing designed to handle blast-furnace gas as primary fuel with natural gas and oil as secondary fuels when the bulk of surplus blast-furnace gas is being utilized for metallurgical purposes. Provision has also been made to use pulverized coal as secondary fuel in the future if and when the price structure warrants such a change.

The boiler and auxiliaries are under the control of an air-operated system, the primary function of which is to supply fuel and air to the furnace in proportion to the steam demand.

When the available blast-furnace-gas supply is insufficient for the steam demand, the secondary fuel normally brought into service next will be natural gas. Alternately, the natural-gas supply may be made the primary fuel by manual manipulation of the selector valves. In such case the blast-furnace-gas supply would be completely shut off.

Normally the fuel-oil supply is closed off, but this fuel may be substituted for the natural gas as a secondary fuel or a supplementary fuel. Separate shut-off valves are provided in each of the two oil-supply lines and minimum stops are furnished on each of the oil-flow regulating valves. Each of the latter controls a supply to four oil burners, one located at each corner of the furnace. By proper operation of the shut-off valves it is possible to bring first one set of four burners into service in response to the control loading-pressure change and after these burners are at their maximum capacity to cut in the second set of four burners. Thus, greater flexibility and good atomization of the oil over a wide range is afforded.

Self-Contained Boilers

During the last several years a new standardized steam-generating type of unit has come into use. Designed originally for the replacement demand in industries requiring small quantities of steam, its development has been such that today it is used in both industrial and central-station plants and for steam conditions ranging up to 700 lb and 850 F, and capacities up to about 250,000 lb per hr.

This unit is generally of the two-drum type with the boiler tubes extended to enclose the furnace. It can be fired with oil, gas or pulverized coal. Requiring no basement and small head room, it makes an ideal low-cost installation where a compact unit is needed to replace antiquated equipment.

Such a boiler fired with oil or gas develops from 80 to 82 per cent overall efficiency. An air preheater can be added to raise this to 84 or 86 per cent, but often it is not done as the increased draft loss necessitates the use of an induced-draft fan. However, pulverized-coal firing requires some means of drying the fuel and an air preheater is often installed for this purpose.

In the paper-mill industry, several of these units have been used in connection with bark-burning stokers located in dutch ovens surmounted by a capacious bark-storage bin.

Ford Motor Company

No paper on industrial power would be complete without reference to the River Rouge Plant of the Ford Motor Company. It is probably the largest industrial power plant in the world and it is also the largest single installation of 1200-lb equipment.

It was designed in 1920 for 240-lb steam. During 1925 and 1926 four of the original 200,000-lb-per-hr boilers were rebuilt to give a capacity of 500,000 lb per hr and water walls, air preheaters and radiant superheaters were added. Subsequent to 1929 this plant was rebuilt in several steps. In 1929 two of the old boilers were replaced with two 1350-lb 760-F units, each with a capacity of 700,000 lb per hr, and one 110,000-kw high-pressure condensing turbine was installed. In 1936 another of the old boilers was replaced by a 1350-lb 915-F boiler of 900,000 lb per hr capacity, and a 110,000-kw high-pressure, condensing, generating unit was installed, together with a 15,000-kw back-pressure turbine for supplying process steam. At present the last of the original low-pressure boilers is being replaced by a 1350-lb 30-F boiler having a capacity of 900,000 lb per hr, together with an additional 110,000-kw turbine.

Each of the 110,000-kw units has the high-pressure element mounted above the low-pressure turbine and the same arrangement applies to the separately excited 55,000-kw generators. In Units 1 and 2, the high-pressure turbine exhausts at 85-lb pressure and is reheated to 560 F by means of steam reheaters before entering the low-pressure cylinder. Higher initial temperatures in later units avoided this. Also, the generators on Units 6 and 7 will be hydrogen cooled.

The 15,000-kw machine generates all the by-product power from process steam, the exhaust at 240-lb pressure going to a battery of evaporators which generate 180-lb steam.

The boilers are of bent-tube design, fired with pulverized coal from a storage system which is supplemented by blast-furnace and coke-oven gas when available. These new high-pressure units should produce a kilowatt-hour for less than 11,000 Btu.

It is interesting to note that the output for 1937 was only slightly less than that generated by the Potomac Electric Power Company and affiliate serving the metropolitan area of Washington, D. C.

Fuels

As stated previously, the fuel selected depends largely on local conditions. By far the fuel most widely used is bituminous coal in pulverized form or on stokers. Bunker C oil and natural gas are available in many localities. In the steel industry blast-furnace and coke-oven gases are utilized when available. However, there remain several uncommon fuels and uncommon uses of ordinary fuels which are of interest.

Anthracite culm accumulates in the mining districts at the rate of millions of tons a year. A small quantity is burned in pulverized form, although its main use is on forced-draft traveling-grate stokers or on hand-fired grates. It is low in volatile and has a high ignition temperature. When burned in pulverized form one difficulty has been to secure sufficiently close regulation of

the primary or carrier air to insure a coal-air ratio approximating that required for maximum speed of flame propagation. Its flame is extremely susceptible to cooling until firmly established; therefore, the secondary air must be admitted to the furnace under careful control.

Culm containing moisture as high as 10 to 15 per cent has been dried satisfactorily by passing preheated air at temperatures of 350 to 400 F through the pulverizers. The power per ton consumed for pulverizing and firing at normal capacity of the system is about 35 kwhr as compared with 10 to 15 kwhr per ton of the usual bituminous coals. The overall thermal efficiency is about 3 per cent lower than that of a similar plant burning pulverized bituminous coal.

In Minnesota, the burning of lignite on traveling-grate stokers by the so-called "short-fire" method has proved successful. The fuel bed travels along undisturbed over the first zones of the stoker where surface ignition occurs and volatiles are driven off. Most of the combustion takes place in suspension as the fuel reaches the blast zone, about half way along the stoker, where high air pressure lifts the fuel from the grate.

At Valmont Station in Denver lignite is burned in pulverized form and the flexibility of operation is much greater than with stoker firing. In this plant, four boilers, each with a capacity of 80,000 lb per hr, are equipped with air-cooled refractory walls, dry furnace bottoms and burners of the down-firing type. The latest boiler with a capacity of 275,000 lb per hr, has water-cooled walls and a wet-bottom furnace.

The Texas deposit covers an area of 50,000 sq miles and the veins average 6 to 9 ft thick at depths of 50 to 150 ft. A number of stoker-fired boiler plants use this fuel successfully, but at fairly low efficiency. About 12 years ago when the Trinidad Station of the Texas Power and Light Company was designed it was decided to burn lignite in pulverized form. The initial installation was so successful that the same method of firing was chosen when the plant was extended in 1931. Operating costs have been favorable compared with fuel oil and natural gas even in a region where these latter fuels have been unusually plentiful. The steam-heated driers plus the drying effect of the mill circuit reduces the moisture content to about 26 per cent. Forced-draft burners are used under straight-tube cross-drum boilers. The furnaces are water-cooled and have dry bottoms. Steam is generated at 450 lb pressure and 750 F temperature. Natural draft is used which prohibits heat-recovery equipment beyond the boiler, but overall efficiencies of 75 to 78 per cent have been attained.

At the Louisiana Steam Generating Corporation, Baton Rouge, La., there are five boilers each with a capacity of 350,000 lb per hr of 620-lb 725-F steam. Natural gas makes up about 70 per cent of the fuel and the remainder is petroleum coke breeze and acid sludges. Bunker C oil is the standby fuel for use when there is no natural gas. All five boilers are equipped to burn natural gas and fuel oil. Four can burn acid sludges in addition to natural gas and oil. Two boilers are able to burn coke breeze in addition to the other fuels. Normally, the procedure is to burn coke breeze and natural gas under two boilers, acid sludges and natural gas under two boilers, and natural gas alone under the fifth unit. From flue-gas analyses there have been worked out for various fuel-burning combinations certain percentages of excess air which give the best combustion efficiency. The percentage of natural gas burned with other fuels varies from 50 to 90 per cent and is the only fuel controlled by the combustion-control system. The automatic fuel corrector adjusts the ratio of natural gas to total air in order to compensate for the quality and quantity of other fuels not under the control system.

In modernized kraft-paper mills, the old picturesque rotary recovery furnace with its rolling barrel 8 or 10 ft in diameter and 20 to 30 ft long, emitting fire and "black ash" at one end and wasting valuable heat up the stack at the other, is rapidly passing from the scene.

Until a decade ago the primary consideration of the kraft-paper industry was recovery of the chemicals in "black liquor," but developments in recovery furnaces accomplish also the generation of steam from the heat formerly wasted. Rates as high as 10,000 lb of steam per ton of pulp are not uncommon.

About 1925 the Wagner spray-type unit was introduced and enjoyed widespread use. The Murray-Waern system is a development involving a combination of heat-recovery apparatus and one or two rotary furnaces, and the Tomlinson furnace was first installed on a commercial scale at Quebec in 1934.

Boiler Feedwater Treatment

At extremely high rates of steam generation, complex scale formation may develop. In this group, the one which has given most difficulty is known as analcite, a complex silicate scale containing sodium and aluminum. Even the use of phosphate or other treatment cannot in all cases prevent the formation of this scale or remove it if it is once formed by the alkaline boiler water. Because of condenser leakage and evaporator carry-over, aluminum and silica cannot be kept out of the boiler water even if the feedwater consists entirely of condensate returns and evaporated makeup. Assurance of very rapid rates of water circulation at the localized hardest-worked sections of the boiler, plus satisfactory external and internal water treatment, is required to minimize the formation of this type of deposit.

With the elimination of scale it becomes necessary to protect the boiler metal from corrosion. The rate of reaction between the water and the steel is increased by the higher temperatures corresponding to the higher pressures. A thin coating of iron oxide integral with the surface of the boiler steel acts as a restraining influence and a protective barrier. The iron-oxide coating will dissolve in highly acid or highly alkaline solution. The minimum caustic concentration which assures protection at boiler feedwater temperatures is that which corresponds to a pH of 9.6 at room temperature. For most operating conditions a boiler-water pH of 10.8 to 11.3 has been found satisfactory. In seams and at other points where restricted circulation and evaporation occur simultaneously, the concentration of alkaline solids may become very high. Under these conditions, and in the presence of silica or certain other agents, the steel may be subject to a selective attack at the grain boundaries which leads to intercrystalline cracking, better known as caustic embrittlement. Fusion welding of boiler drums has minimized this source of trouble.

Many boiler feedwaters have a pH not far from the neutral point, or 7.0, and are treated to bring the alkalinity up to boiler requirements. Fig. 6 shows some interesting data on pure neutral distilled water and indicates why such untreated water in a high-pressure

boiler could be dangerous. At 0 C, the pH value is 7.44; it crosses the standard neutral point of 7.0 at 22 C, and reaches its lowest value of 5.58 at 250 C. Since the water contains no free acidity or alkalinity, its own acid and alkaline characteristics are balanced, i.e., it is neutral at each of these points. However, at the higher temperature, both the acid and the alkaline properties of the water are more than ten times as active as at room temperature.

Even when the boiler water contains sufficient alkalinity to inhibit corrosion, it is imperative to remove

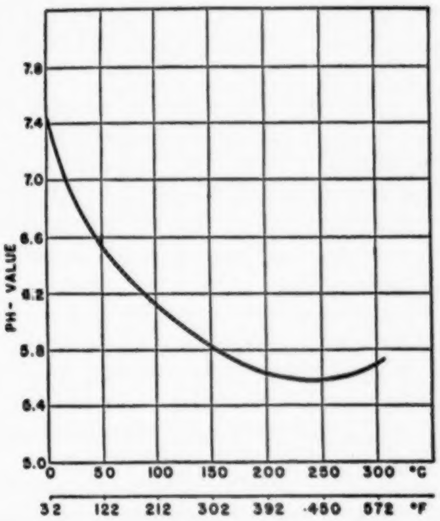


Fig. 6—Relation of pH Value to temperature for pure distilled water

completely dissolved oxygen if corrosion is to be prevented. The first step in removal of oxygen is mechanical deaeration, which is capable of reducing the oxygen content of the water to an amount too small to measure analytically. The last traces of the oxygen may be removed by the use of chemicals, the most popular being sodium sulphite. The latter should not be considered as a substitute for mechanical deaeration, but only as a secondary line of defense.

The pretreatment of water in apparatus external to the boiler to make it suitable for feedwater makeup is most commonly accomplished by either the lime-soda process or the zeolite process, each of which has many modifications. The lime-soda process is more generally adaptable where the raw water is turbid or contains free acid, iron or excessive hardness. It is adapted to the use of supplementary chemicals to accomplish various results. The lime-soda process may be carried out on either hot or cold water; since the reduction of hardness and the speed and efficiency of the process are greatly increased at higher temperatures, hot-process softeners are widely used. The less complete degree of softening that is effected in cold water would, in many cases, be inadequate for the preparation of boiler feedwater. A recent development for treating relatively soft waters, with hardness not exceeding 3 ppm, is primary phosphate hot-process softening. This effects softening and coagulation in a single-reaction and settling tank, and zero hardness may be obtained. For very hard waters, similar results can be secured in two steps—the less expensive lime and soda in the first stage to remove the bulk of the hardness, and the economical use of phosphates in the second stage.

Zeolite systems are capable of reducing the hardness of water to a few parts per million and are suitable where the hardness varies considerably, since the softening reaction is more or less automatic and does not depend on instantaneous adjustment of chemicals to the quality and volume of the water. A clear and approximately neutral water supply must be provided for this treatment. It is sometimes combined with cold-process softening as a pretreatment and is frequently preceded by coagulation and filtration systems.

Evaporators

Years ago the use of an evaporator in connection with boilers was limited to seagoing vessels where distilled fresh water from sea water was used as makeup. The adoption of higher steam pressures coupled with a question as to the ability to successfully treat feedwater for the higher pressures led to the development of evaporators, and this trend has progressed to a point where evaporators of large sizes have been installed to produce low-pressure steam for process work. In such cases they are used as heat transformers generating low-pressure process steam and returning the clear condensate to the boiler-feed system.

Triple-effect evaporators are sometimes installed to supply steam demands that vary greatly. When more steam for process is required, the unit is operated on the double-effect principle.

With the adoption of the regenerative cycle and wider use of motors for auxiliary drives, the makeup requirements for turbine-driven plants were reduced to 1 or 2 per cent. Moreover, the several extraction points on the turbines offered ideal conditions for the installation of single-effect evaporators between bleed points, with a lower pressure feedwater heater acting as the evaporator condenser. General practice follows this arrangement today and nearly all of the 1200-lb installations in central stations use evaporators for small quantities of makeup.

Conclusion

One indispensable item in engineering of industrial plants is the economic result obtained, i.e., the return on the money invested. Most industrials, due to changes in production and processes, require returns of at least 25 per cent gross before embarking on an expenditure made solely on the score of economy. Conditions are somewhat different in the utility industry where there is a wide diversity of load and therefore a much better load condition. Consequently, utilities are not faced with changing processes which cause early obsolescence of equipment. While it is seldom found economical to replace steaming and power-generating equipment which is in reliable operating condition, there are cases where it is necessary to replace portions of the plant due to obsolescence or for other reasons and, in such cases, the replacement cost of this item should be credited to the total cost of the new development for providing both steam and power generation in order to arrive at the net cost of the power development to be justified.

Load Distribution on Turbine-Generators

By Y. C. LU
Shanghai Power Company

In contrast to the usual procedure of computing incremental input based on steam rate test data, which involves corrections for back pressure as applied to the several units, the author outlines a method based on figures taken from the daily log sheets for the period of a year which includes condenser performance. This enables the turbine test data to be corrected for circulating water temperature and both turbine and condenser to be treated as a single unit. The values assumed for the curves are hypothetical. In the May 1938 issue the author had an article dealing with "Load Distribution on Boilers."

IN considering load distribution among similar units, whether they be boilers, turbines or plants of a system, it cannot be overemphasized that the units in question be put on a truly comparable basis.

Take for example the proper load distribution among steam turbines. The usual procedure is to make steam rate tests at various loadings on each turbine and from the test data, input-output curves are drawn, incremental input is computed for each machine and then a load distribution schedule is laid out by the method of equal increments.

However, due to operating conditions, these tests can seldom be made under exactly the same conditions, hence the test data are reduced to standard conditions by a set of correction curves which in most cases are supplied by the manufacturers. Care should be taken, that these standard conditions, such as steam pressure, steam temperature and circulating water temperature, are common to all the turbines.

Unfortunately, to correct turbine steam rate test figures to a standard circulating water temperature involves an indirect process. So, instead, the test figures are sometimes corrected to a standard back pressure, a process which is much easier and more direct but may lead to erroneous conclusions and consequently false economy. The reason is evident, for correcting to the standard back pressure means comparison of only the turbines without considering the condensers. It is the combined performance of turbines and condensers as single units that we are seeking for the true economy of a station.

The relation of back pressure and circulating water temperature is not as simple as represented by the guarantee curves given by the condenser manufacturers. The back pressure in a condenser depends on (1) effectiveness of the air removing apparatus, (2) velocity of the circulating water, (3) temperature of the circulating water, (4) rate of steam condensation, i.e, the load on the turbine and (5) cleanliness of the condenser tubes. Even though one considers the first two items to be constant, the back pressure for a certain load and circulating water temperature still varies greatly according to the cleanliness of the tubes.

It is possible to conduct several tests on condensers at different periods after cleaning, yet the results obtained therefrom may not warrant the expense involved.

The following is an attempt, which is believed to be reasonable and convenient, to solve the problem by utilizing the figures on daily log sheets.

From the daily log sheets of each turbine, the average figures for turbine load, back pressure and circulating water temperature for each week are found and plotted with back pressure as the ordinate, circulating water temperature as the abscissa and with load marked on each point. Fig. 1 shows such points for a whole year for a 15,000-kw turbine.[1] Some points are omitted for the sake of clearness. Through the points of approximately the same loading, several curves are drawn to represent the relation between back pressure and circulating water temperature at certain turbine loadings. Since these curves are based on the daily figures throughout one year, they can be assumed to represent the condenser performance for the average cleanliness of the tubes.

According to the range of circulating water temperature of different localities, turbine loading schedules can be made for several seasons. In Fig. 1 for instance, a water temperature at 45 F may be taken as the standard temperature for winter, 85 F for summer and 65 F for spring and fall. Only the curves at 65 F are here taken for illustration.

At 65 F there are two curves—one for turbine load of 10,000 kw and another for 11,000 kw. If a straight line be drawn tangent to each curve at 65 F, these lines will indicate the rate of change of back pressure with respect to circulating water temperature. The rate at the point *A* is 0.26 in. Hg for 10 deg change in water temperature. At the point *C*, this figure is 0.24 in. Hg. The average figure 0.25 will mean that the average change in back pressure is 0.25 in. Hg for every 10 deg change in circulating water temperature for the season of spring and fall, irrespective of turbine load and cleanliness of tubes. Also it will be noted from Fig. 1 that the average back pressure at 65 F is 1.25 in. Hg.

[1] Data used in this article are hypothetical.

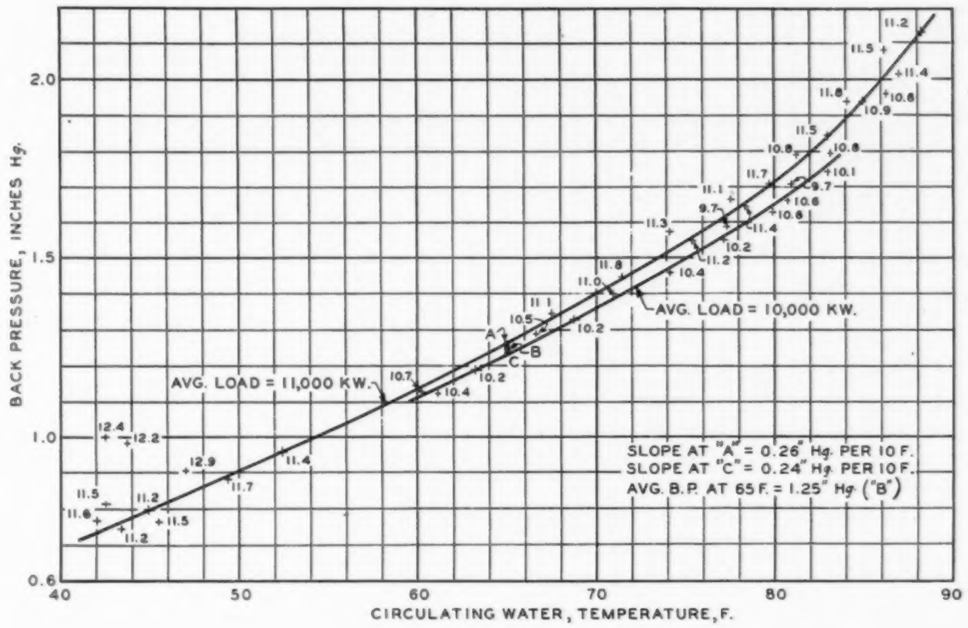


Fig. 1—Relation between back pressure and circulating water temperature

Figures marked on each point signify the average load for the week; for example, 10.4 means an average load of 10,400 kw.

Once these figures are obtained, one may turn to the turbine correction curve for back pressure as that shown in Fig. 2. The scale for back pressure may now be transformed to that of circulating water temperature by fixing 65 F in the place of 1.25 in. Hg and laying the scale in the ratio of 10 degrees to 0.25 in. Hg back pressure.

The turbine test data will then be corrected for circulating water temperature instead of back pressure. In this way the condenser performance is incorporated in the correction curves and turbine and condenser are thus treated as a single unit.

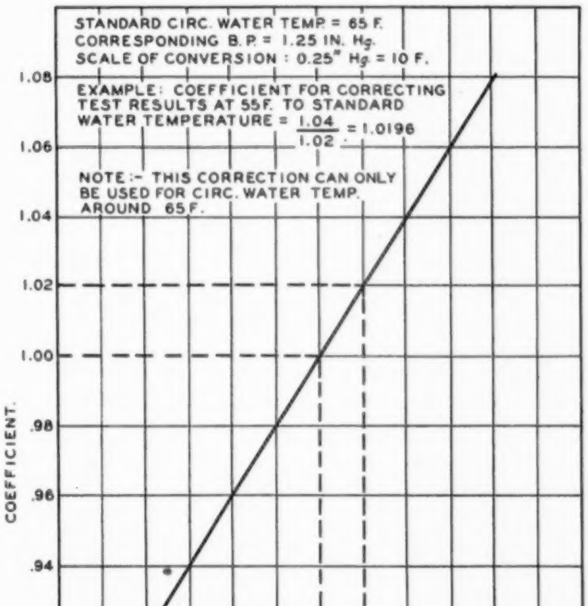


Fig. 2—Conversion of correction curve for back pressure to correction curve for circulating water temperature

For more accurate results, average daily figures may be plotted in Fig. 1 instead of weekly figures and the slope on the curves may be taken at every 10 deg of circulating water temperature. The process may be as refined as time and expense permit. Care should be taken, however, to exercise good judgment in drawing the most representative curves through the points in Fig. 1, because on the slope of these curves depends the accuracy of results.

Sometimes only one curve is necessary as a certain turbine may be operated at almost constant load or its back pressure may not be affected very much by the load.

Loading at Equal Increments and Load-Duration Curve Combined for True Economy

Although the turbines have been compared on a true basis and incremental input curves worked out, there still remain some other problems to be solved in order to obtain true economy. A hypothetical case will be taken for illustration.

Suppose it is required to work out a loading schedule for four available steam turbines in a station. Two are of 20,000 kw each (designated as *A* turbines) and the other two are of 10,000 kw each (designated as *B* turbines). The daily variation of station load is from 25,000 kw to 50,000 kw. The loading at equal incremental inputs is supposed to have been worked out as follows, assuming a steam cost of 70 cents per 1000 lb.

A Turbines		*B* Turbines	
Load	Input	Load	Input
20,000 kw	$179.00		
19,000 "	169.00		
18,600 "	165.00	10,000 kw	$94.50
18,000 "	159.10	9,300 "	87.20
17,000 "	149.30	8,500 "	79.20
16,000 "	139.70	7,500 "	69.50
15,000 "	130.70	6,700 "	62.00
14,000 "	121.80	5,800 "	54.00
13,000 "	113.30	5,000 "	47.20
12,000 "	105.30	4,000 "	39.50
10,000 "	89.30		

In the above table the input in dollars is supposed to consist of fuel cost alone. Maintenance cost and overhead charges may be added in for more refined calculation. Here a simple case is sufficient to illustrate the point. The steam cost which has been assumed with

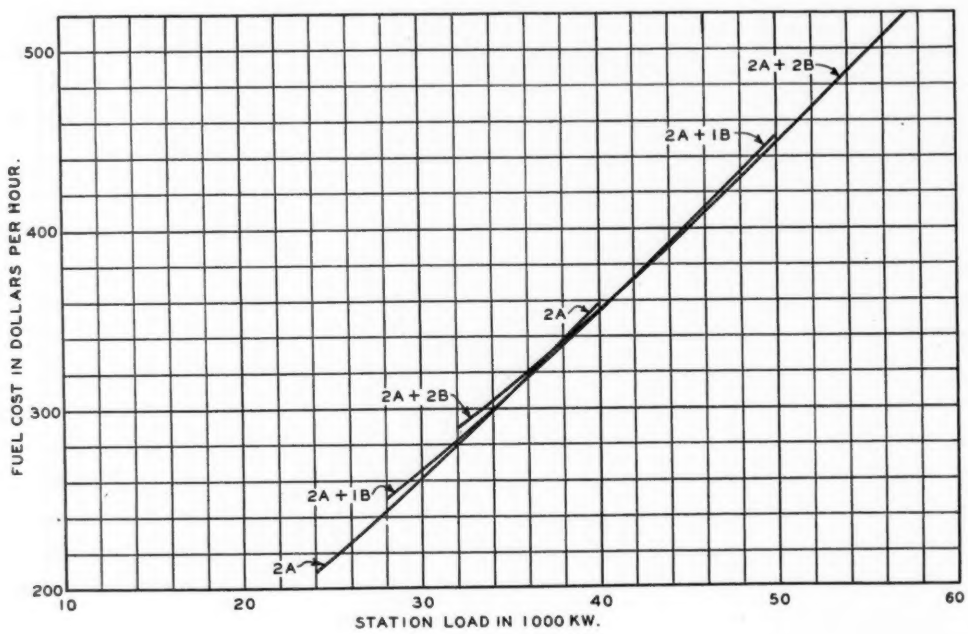


Fig. 3—Input-output curves for different combinations of turbines loaded at their equal incremental inputs

reference to certain local conditions outside of the United States may appear unduly high, but it will not influence the principle that is being presented.

Based on loading at the equal incremental input, a set of input-output curves for different combination of A and B turbines are worked out and shown in Fig. 3. A glance at these curves will indicate that between the station load of 45,000 and 50,000 kw, two A turbines plus two B turbines would be more economical than two A turbines plus one B turbine. This would involve bringing one more 10,000-kw machine on load in order to effect this saving which means that some quantity of steam must be consumed in bringing the machine up to speed. The question now is to weigh the gain on the two sides and see which is really the more economical combination. Suppose steam for starting the turbine is found by test to be one pound per kilowatt of rated capacity, the fuel cost for starting one 10,000-kw turbine would be

$$\frac{0.70}{1000} \times 10{,}000 = \$7.00$$

The saving of two A + two B over two A + one B will depend on the load characteristics of the station. The station load between 45,000 and 50,000 kw in this case will be very carefully checked and recorded.

Fig. 4 shows a portion of the daily load-duration curve of the station. On this portion take any number of convenient points, for each of which find the corresponding input for both two A + two B and two A + one B from the curves on Fig. 3. The result is two fuel input curves, one for each combination of turbines. The area between these two curves is evidently the saving in fuel cost of two A + two B over two A + one B. It is found to be $6.00, while the steam for bringing one more turbine on load would cost $7.00.

This shows that the loading at strictly equal incremental inputs may not always yield the minimum total cost. Careful investigation into the particular operating conditions is necessary for obtaining the most economical result. Where it is necessary to provide spare turbine capacity to take care of unexpected outage of a unit, the load distribution will, of course, be influenced, but this involves the question of reliability which is aside from the present discussion.

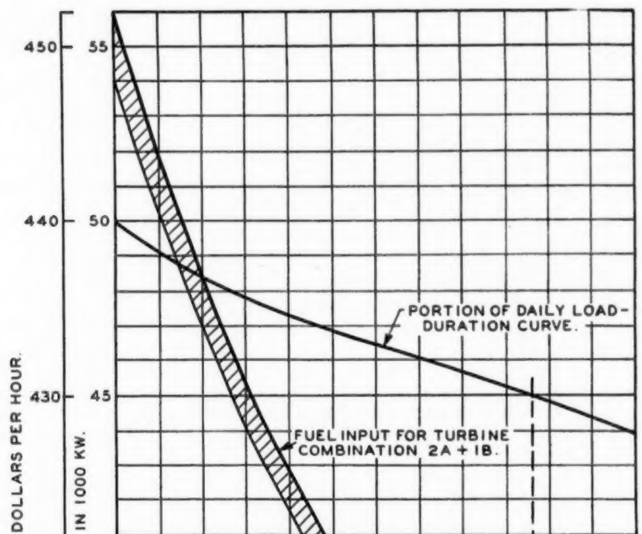


Fig. 4—Daily load duration and fuel-input curves

Some Fundamentals of Feedwater Treatment

Numerous articles have been published dealing with various phases of feedwater treatment, but, in view of the complexity and many ramifications of this subject, it is believed that some readers would welcome a review of certain fundamentals. These were clearly and simply stated in a recent informal talk before a small group of engineers, which is here reproduced.

BOILER feedwater is treated to prevent scale and corrosion. In general two kinds of waters are used for feeding boilers, namely, treated raw water, usually referred to as "makeup," and condensate. Raw water for treatment may come from city water supply, rivers or private wells. Condensate is the steam condensed in a condenser after passing through the turbine.

Raw water contains minerals in solution. Water is a good solvent; it dissolves minerals with which it comes in contact. As it flows over or through the earth it dissolves the minerals over which it flows.

Scale-Forming Materials

The scale-forming minerals are the calcium and the magnesium compounds. They occur in water mostly as carbonates and sulphates. The common limestone is calcium carbonate from which lime is made. Lime is used to make plaster or mortar because it sticks to surfaces. Calcium sulphate is used to make gypsum or plaster of paris and is used for hard plaster and plaster casts. The magnesium compounds are less plentiful. The most familiar form of a magnesium compound is magnesia which is magnesium oxide used in pipe covering. Calcium and magnesium carbonates and sulphates dissolved in boiler water produce hard scale which may cause overheating of the metal. Scale is particularly objectionable in water-cooled furnace walls, because they are exposed to high furnace temperature and may be damaged by heat if scale is allowed to deposit in them.

Raw water should be treated in separate water treating plants to remove the scale-forming calcium and magnesium compounds. The most commonly used water treatment for this purpose is the hot lime-soda process. Lime is used to reduce bicarbonate to simple carbonates, and soda or soda ash to reduce calcium and magnesium sulphates to sodium sulphates and to drive the calcium and magnesium carbonates out of solution, and cause them to precipitate. These precipitates are allowed to settle and are drained off as sludge.

Another feedwater treatment is the zeolite process which accomplishes results similar to the hot lime-soda treatment; that is, it removes most of the scale-forming calcium and magnesium compounds. These processes are called the primary treatment.

The treated water contains mostly sodium carbonates and sulphates, both of them non-scaling, and a very small amount, 20 to 30 parts per million, of the calcium and magnesium compounds which are made harmless by a secondary treatment with sodium phosphate.

Phosphate treatment is supplied directly to the boiler, preferably through a separate line. The sodium phosphate changes the calcium and magnesium carbonates and sulphates to phosphates which are precipitated in the boiler as sludge and mostly removed by blow-down. Phosphates do not make hard scale. If any phosphates are deposited in the boiler they usually can be washed out with a hose.

If sodium phosphate were supplied with the feedwater, it would cause deposits in the feed pump, feed line or economizer and clog them. For this reason it is necessary to supply it directly to the boiler through a separate line. It is supplied intermittently and is fed through the line at high velocity to prevent deposition. After each dose of phosphate the lines are purged with clean water to remove any phosphate solution.

Condensate which contains only the small amount of impurities brought in by condenser leakage is usually treated within the boiler with caustic soda to neutralize any acids and to raise the pH value. It is also treated with sodium phosphate to render harmless any calcium and magnesium compounds that may get into the condensate through condenser leakage. One should remember that the steam side of the condenser is always under high vacuum, and the cooling water is above atmospheric pressure; therefore leakage in the condenser causes the cooling water to flow into the condensate. As with treated makeup water, the phosphate should be supplied directly to the boiler through a separate line.

There are certain compounds of silicon which make very hard scale in the boiler and which are difficult to make harmless by water treatment. Fortunately, most of the feedwater is free from silicon compounds in sufficient quantity to make them troublesome. Silicates, to a large extent, may be removed in pretreatment and may also be rendered harmless by treatment within the boiler.

Corrosion

Boiler corrosion is of three kinds, that due to acid water, oxygen corrosion and corrosion of dry areas of active heating surfaces. Corrosion due to acid water is general in extent; it is usually slow but covers large areas. The water may be acid because there is a small amount of acid dissolved in it, or, it may be too pure and act as weak acid. When hydrogen is burned with chlorine, the product is hydrochloric acid which is a strong acid that

dissolves iron very fast. When hydrogen is burned with oxygen the product is water which may be considered a very weak acid dissolving iron slowly. To prevent the water from dissolving the iron of the boiler, the water is made alkaline by the addition of soda ash (sodium carbonate) or caustic soda. In other words, since water has the desire to hold something in solution, this desire is satisfied by the addition of soda ash or caustic soda which also has the capacity to neutralize any acids that may get into the water by condenser leakage. As a rule, treated makeup water is highly alkaline and does not need the addition of alkali. On the other hand, condensate, being nearly pure water, requires the addition of some caustic soda. The amount of alkalinity in the boiler water varies from about 30 parts per million with condensate as feedwater to about 500 parts per million with treated makeup water. Too high alkalinity is objectionable because it tends to produce wet steam. The alkalinity is usually expressed in equivalent parts per million of carbonates. Alkalinity is a measure of the capacity to neutralize acids.

Means for Eliminating Oxygen

Oxygen corrosion is due to oxygen dissolved in feedwater. The oxygen combines with the iron of the boiler and forms black oxide of iron. Corrosion occurs in spots and, if allowed to continue, forms deep pits. Complete deaeration of the feedwater is the solution for oxygen corrosion. This is accomplished in deareating feedwater heaters. Steam must be supplied to heat the water to the boiling point so that the oxygen can be boiled out of the water and vented from the feedwater heater.

In high-pressure installations, complete deaeration is very important because the oxygen is very active at high temperatures and at high pressures. Therefore, in many such installations, oxygen scavengers are added to the feedwater after it has passed through the deaerating feedwater heater in order to remove the last traces of oxygen. Ferrous hydroxide or Akon, a finely divided metallic iron, are frequently used for this purpose. For lower pressures sodium sulphite is sometimes employed but it is not recommended for high pressures.

Ferrous hydroxide picks up the traces of oxygen and oxidizes to ferric hydroxide which drops out of solution and is removed through a blow-down. Akon is a finely divided iron which stays in suspension in the water throughout the boiler. Because of this thorough distribution, it picks up the last trace of oxygen and combines with it before the oxygen has a chance to attack the boiler. It is also credited with the prevention of the silicon compound scale. The sodium sulphite when used as an oxygen scavenger oxidizes with the last traces of oxygen in the boiler water to sodium sulphate.

Corrosion in the dry area of the active heating surface of the boiler is oxygen corrosion. The oxygen causing this corrosion apparently comes from the decomposition of steam or water due to elevated temperatures of the dry areas. It seems that this type of corrosion is worse with high alkalinity and high pH value of the boiler water. While ordinarily the pH value of boiler water is carried as high as 11.5, when there is a tendency of corrosion of the dry areas, it is recommended that the pH be reduced to about 9.5.

Although the pH value rises and drops with alkalinity, there is no exact relation between the two; that is, there is no factor by which alkalinity can be multiplied to obtain pH value. Alkalinity and pH are measures of two different things. Alkalinity is the measure of the capacity to neutralize acids, whereas pH value is a measure of the concentration of hydrogen ions in boiler water. Alkalinity is a chemical property and pH is somewhat an electrical property. A small part of the water is separated into positive hydrogen ions H^+, and negative hydroxide ions OH. The product of the concentration of H^+ ions multiplied by the concentration of the OH ions is a constant. If the concentrations are expressed in grams per liter, this constant is equal to $\frac{17}{10^{14}}$. When the pH value is 7, the H^+ concentration is $\frac{1}{10^7}$, and the OH concentration is $\frac{17}{10^7}$. When the pH value is 9 the H^+ concentration is $\frac{1}{10^9}$, and the OH concentration $\frac{17}{10^5}$. That is, the pH value is equal to the number of ciphers in the denominator of the fraction expressing the concentration of H^+ ions. This statement is true only when the pH value is an integer; when it contains a fraction, as for example 9.6, the denominator cannot be put down as 1 followed by 9.6 ciphers, but must be written as $10^{9.6}$. For that reason the pH value is defined as the logarithm of the reciprocal of the concentration of the H^+ ions, when the concentration is expressed in grams per liter.

It is obvious that the smaller the concentration of the H^+ ions the higher is the pH value. Also, since the product of the concentration of H^+ ions multiplied by the concentration of negative OH ions is constant, the higher the pH value, the higher is the concentration of the negative ions.

Boiler feedwater is never pure; it always contains minerals in solution. These minerals are either originally in water, or are added during feedwater treatment. Water evaporates and leaves the boiler as steam while the minerals stay in the boiler. The concentration of the minerals in the boiler water is 10 to 100 times that in the feedwater. To prevent excessive concentration in the boiler water, the boiler is blown down. The amount of blow-down is very small with a condensate feedwater, but may be large with treated makeup water.

The steam is made from the highly concentrated boiler water. Some of the minerals may be carried out with the steam and deposited in the superheater or on the turbine blades, thus causing reduction in efficiency and capacity. It is, therefore, desirable that the steam be purified before it leaves the boiler. The most effective method of purification is steam washing which is a process of passing the steam on its way from the boiler through the incoming feedwater. Steam that has passed through a steam washer should have about the same small amount of impurities as it would have if made from the feedwater instead of from the highly concentrated boiler water. In other words, when a steam washer is used the purity of steam depends largely on the concentration of feedwater and not on the concentration of boiler water. A steam washer makes it possible to carry higher concentration of boiler water without affecting the purity of steam, thereby reducing the losses in boiler blow-down.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Overfire Air

Results of investigations on the effect of secondary air jets in a stoker-fired furnace were reported by Professor P. Koessler in the July 1938 issue of *Archiv für Wärmewirtschaft und Dampfkesselwesen*. These tests were made with a furnace having a volume of approximately 1060 cu ft and a traveling-grate stoker of 65 sq ft area. A combustion rate of about 18 lb of coal per square foot per hour was maintained. Five secondary air jets were directed downward through the front arch into the flame at an angle of 20 deg from the horizontal. The influence of air pressure and nozzle areas was studied. Readings were taken at 160 points in the furnace, of which 45 were made simultaneously.

As an approximate measure of the completeness of combustion at these various locations the following ratio was determined from the analyses of the gases:

$$\frac{CO_2}{CO_2 + CO + MC_mH_n + CH_4}$$

When the gas sample contains only CO_2 this expression becomes one. These values are represented by the outlines indicated in the accompanying sketches which are plotted from readings taken in a vertical plane passing from front to back through the center of the furnace. Fig. 1 shows results with an air pressure of about 9 in., water gage and an area of 1.55 sq in. for each of the five nozzles. Practically complete combustion is indicated at a distance of about five feet above the grate.

Fig. 2 shows the results with the same nozzle area but a pressure of only $4^1/_2$ in. of water. That is, the velocity of the overfire air is much less and the level at which combustion was complete was raised considerably.

The readings plotted in Fig. 3 were made without secondary air injection and show only a small area in the upper rear section of the furnace where combustion was complete.

Other curves, not here reproduced, showed the influence of varying the nozzle area. With the same air velocity, combustion was improved at the lower levels of the furnace by employing larger nozzles.

From these studies a general recommendation was made for a minimum of 7 per cent secondary air and a velocity of 160 to 200 ft per sec.

Sulphur and Dust Extraction at Fulham

Further information on the flue gas washing equipment at the Fulham Power Station, England, is contained in the November issue of *Industrial Power and Fuel Economist.*

This equipment is the Howden-I.C.I. recirculating non-effluent water system in which the sulphur and dust in the flue gas are absorbed and discharged from the washing circuit as solids. At Fulham, lime is added to the washing water to neutralize the acid constituents of the flue gases. This lime rapidly combines with the CO_2 dissolved in the water and produces chalk, which is insoluble, and calcium bicarbonate, which is soluble. The calcium bicarbonate absorbs the acid constituents, and as absorption and neutralization proceed, fresh calcium bicarbonate is formed from the chalk.

During the passage of the washing water through the

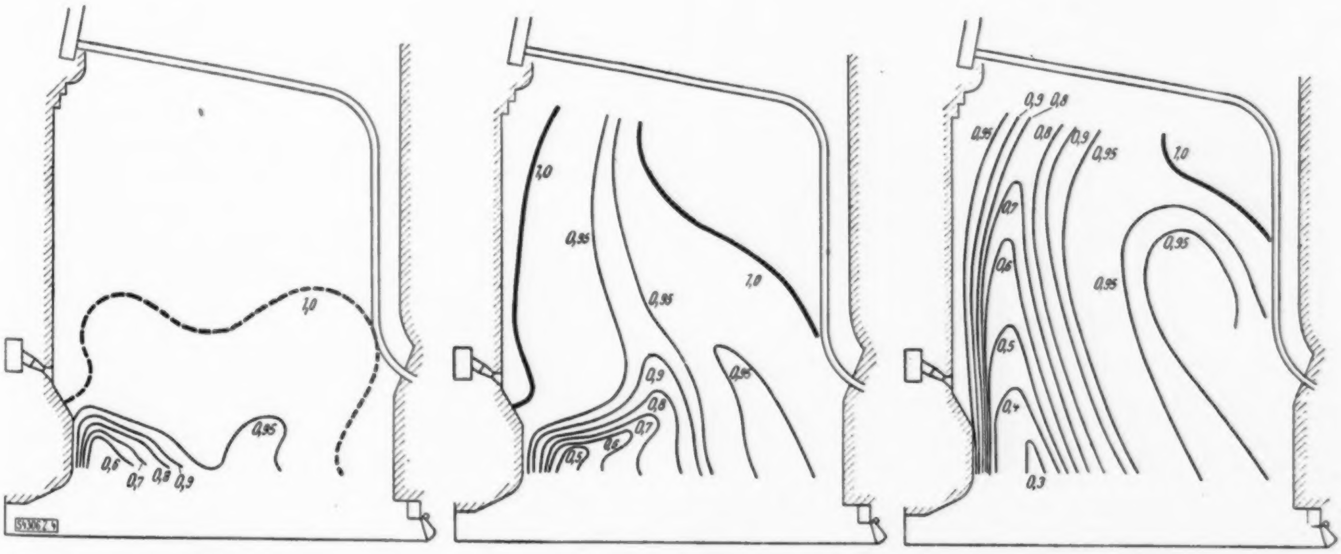


Fig. 1 Fig. 2 Fig. 3

Diagrams representing completeness of combustion along a vertical plane through center of furnace

Fig. 1 shows conditions with an injection air pressure of 9 in.; Fig. 2 with $4^1/_2$ in. air pressure; and Fig. 3 without overfire air.

scrubber, the liquid becomes supersaturated with calcium sulphate and calcium sulphite. Desupersaturation takes place during the delay period and the formation of the solids from the scrubber takes place outside the scrubber.

Most of the coarse dust, namely, about half the total, and a large portion of the SO_2 are removed in the primary element section which constitutes only from 10 to 15 per cent of the entire packing surface. The final scrubbing is effected in a special grid type packing composed of wooden laths staged on top of one another, the laths of alternate grids being at right angles to one another. The gases after rising through these grids pass through spray eliminators, then through the outlet ducts to the induced-draft fans. By placing the fans after the scrubber there is a saving in power consumption of 50 hp per boiler due to handling a smaller volume of cooler gas.

As the gases pass through the grid packing, turbulence is appreciable and the humidified particles are thrown onto the liquor film.

From the grids and primary elements the liquor passes into the large capacity delay pipes and is pumped back eventually to the head tanks. To protect against erosion, portions of the system, where the velocity of the liquor is high, are lined with rubber. The milk of lime or chalk for neutralization of the absorbed SO_2 is added continuously at a point in the system after the liquor leaves the scrubber and before it enters the delay tanks.

The addition of milk of lime is controlled automatically at a rate proportional to the boiler load, so that the pH value leaving the primary elements is around 6.8. The rate of flow of the recirculating liquor through a complete washer for one boiler is 13,000 gallons per minute. Each complete unit is capable of handling 105,000 cu ft of gas per minute.

The sulphur content in the gases and vapor leaving the Fulham chimneys is usually as low as 0.006 grains per cubic foot, which is well below the permissible figure of 0.03 grains per cubic foot and corresponds to an extraction efficiency of over 99 per cent.

The efficiency of dust extraction is also high as only traces of dust of sizes less than 5 microns pass out into the atmosphere.

Electric Boilers in Switzerland

According to the November issue of *The Brown Boveri Review*, the total load of electric boilers in Switzerland amounts to about 240,000 kw, distributed as follows:

Textile industry	40,000 kw
Paper mills	35,000 kw
Breweries	25,000 kw
Chemical works	45,000 kw
Food industries	26,000 kw
Hospitals and central heating	38,000 kw
Other plants	31,000 kw

These plants utilized approximately 430 million kilowatt-hours of electricity in 1937 at an estimated saving of 70,000 tons of coal, inasmuch as they operated on energy from hydroelectric plants. Incidentally, Switzerland has a large surplus of water power that is wasted and is equivalent to about 250,000 tons of coal annually. This, it is pointed out, offers an attractive field for the application of electric boilers for heating.

The article lists the installed power of electric boilers in countries other than Switzerland as,

Finland	230,000 kw
Sweden	180,000 kw
Norway	170,000 kw
Italy	110,000 kw
Germany	100,000 kw
England	90,000 kw
France	80,000 kw
Other countries	60,000 kw

The total capacity is equivalent to over 5 million pounds of steam per hour.

Large Mine Power Plant

A sizeable French colliery power plant is described in the November issue of *Technique Moderne*. This plant, providing mine power at the Société des Charbounages de Foulquemont, is designed for a capacity of 80,000 kw. There are installed at present three 70,000-lb per hr boilers supplying steam at 550 lb pressure, 840 F, to a 13,000-kw turbine-generator, but additional boilers each of 140,000 lb per hr capacity and two 26,000-kw turbine-generators, in addition to 15,000 kw in turbine-compressor capacity, will soon be added. Mine waste containing 35 to 45 per cent ash is burned on stokers. Condenser circulating water is handled by cooling towers.

Clarence Dock Extension

Engineering and Boiler House Review for December contains a detailed description of the extension to the Clarence Dock power station at Liverpool which was officially placed in service on October 18. The original portion of the station, built in 1931, contains two 50,000-kw turbine-generators provided with steam at 450 lb, 750 F, by eight stoker-fired boilers, four of 176,000 lb and four of 250,000 lb per hr maximum capacity. The present extension consists of six 250,000 lb per hr straight-tube, single-drum, stoker-fired boilers supplying two 50,000-kw turbine-generators with steam at 630 lb and 825 F total temperature. Thus the present capacity of the station is 200,000 kw. The cost of the addition was equivalent to $85 per kw.

The new boilers have fusion-welded drums and are provided with economizers and tubular air heaters. Dust collectors of the centrifugal type are employed. Each boiler has two 74-in. induced-draft fans of the radial-blade, single-inlet type driven through hydraulic couplings, and two 47-in. backward-blade, double-inlet, forced-draft fans. The stokers are of the twin traveling grate type, the grate area for each pair being 29 ft wide by 22 ft long. Two reinforced-concrete chimneys, 325 ft high and 28 ft diameter at the base, serve the old and new boiler rooms. These chimneys are independent of the boiler house.

The two new turbine-generators, of the tandem type, have twenty-eight impulse stages and sixteen impulse stages, with duplex exhaust. At the normal economic load of 41,200 kw all the steam is admitted to the first stage while for higher loads up to the maximum, additional steam is admitted between the sixth and seventh stages of the high-pressure cylinder. Feedwater heating

is carried out by three high-pressure and two low-pressure heaters in addition to a gland-steam heater and the temperature to the economizers is 342 F. There are also double-effect evaporators designed to supply 5 per cent makeup.

The condensers have welded shells and a chlorinating plant has been provided to treat the circulating water for the handling of algea.

British Output of Electricity Shows Increase

The eighteenth annual report of the British Electricity Commissioners, covering the fiscal year ending March 31, 1938, has recently been published. This shows a total annual production of over 23 billion kilowatt-hours, representing an increase of 11.9 per cent over the preceding twelve months. Some of this increase is undoubtedly traceable to the rearmament program. Fuel costs have increased to an appreciable extent in the last few years, but there are fuel clauses in the contracts covering electric rates which make provision for such advances in the price of fuel.

The progress of centralization of generation has continued, as is shown by the fact that 39 out of 424, or 8.2 per cent of the central stations, contributed nearly 70 per cent of the total energy produced. Extensions sanctioned by the Commissioners reached 645,000 kw, for which loans amounting to the equivalent of nearly a hundred million dollars were made. Of these loans about one-third the total was for generating equipment and the remainder has been applied to facilities for transmission and distribution.

The report quotes from the 1935 British Census of Production showing that approximately one-half of the electricity consumed was privately generated.

South African Plant Adds New Unit

Industrial activity in South Africa during the past few years has been such as to require considerable expansion in power generating facilities. The construction program for the 424,000-kw Klip Generating Station was referred to in these columns several months ago and the extension to the well-known Congella Station at Durban is described in the November issue of *Industrial Power and Fuel Economist* (London) from which the following notes are taken.

This station was constructed in 1928 and then contained four boilers. There were added two more in 1929, two in 1932 and two have just been placed in service. All are of the International Combustion steam-generator design. The new units are each of 120,000 lb per hr capacity, 270 lb pressure and, like the previous units, are fired with pulverized coal from a storage system. Each is provided with an air preheater and the leaving gases are passed through an electrostatic precipitator placed on the suction side of the induced-draft fan to reduce the possibility of abrasion of the fan blading and casing. Complete combustion control of the Bailey type is provided on the new units.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Blow-off Valves

Two new 24-page bulletins, one dealing with blow-off valves for high-pressure boilers and the other for low and medium pressures, are being distributed by the Yarnall-Waring Company. These describe and illustrate construction details of the several types of "Yarway" valves and include tables of dimensions, weights and prices. Space is given to the physical and chemical properties of the materials employed for different parts and typical installation views are shown.

Boiler Settings

A 48-page catalog in color has been issued by Plibrico Jointless Firebrick Company dealing with settings for water-tube boilers. These include firebox linings, suspended arches, sectionally-supported air-cooled settings, flexo-anchors, Plicast lining, Plicast tube decks forming a monolithic covering over circulating tubes, linings for ash pits, Beco-Turner baffles and observation ports and backing for water walls. Directions for installation are given in detail and illustrated by suitable photographs and prints.

Coal-Handling Equipment

A 48-page bulletin, No. 83, prepared by The C. O. Bartlett & Snow Company deals with its line of coal-handling equipment as applied to central stations and to industrial boiler plants of 5000 hp and less. Complete equipment and partial installations are discussed including skip buckets, track hoppers and hopper pits, weigh-type loading gates, skip hoist runways, hoist engines, coal bunkers, cars, weigh larries, ash hoppers, gate mechanisms, elevators and conveyors and field storage. The bulletin is profusely illustrated with installation pictures, and blueprint reproductions show details and dimensions of the equipment.

Combustion Control

The Hays Corporation has issued a 40-page brochure on centralized combustion control for steam power plants of all sizes. Included are pressure controls, draft controls, both hydraulic and electric remote pilot pressure controls, high differential pressure controls and low differential pressure controls. In each case the scheme of operation is discussed and illustrated in detail and the construction described.

Supplementing this is an 8-page pamphlet dealing with the design and manufacture of boiler-room panels.

Continuous Blowdown

Elgin Softener Corporation has issued bulletin No. 510 which presents a treatise on the subject of continuous blowdown systems for steam boiler plants. The need for such systems is illustrated by typical plant studies with useful charts and tables. The latter also point out savings to be realized with heat exchangers.

Electric Instruments

A 180-page loose-leaf catalog by the General Electric Company deals with an extensive line of electric meters and instruments, including those of the indicating switchboard and panel types, recording and portable indicating instruments, testing sets and accessories, portable transformers, shunts for d-c instruments, oscillographs, precision instruments, etc. Price lists are included.

Feedwater Regulators

Bulletin S-20-D recently issued by The Swartwout Company describes its line of feedwater regulators and differential pressure control. It is fully illustrated with photographs, diagrams and hook-ups in color.

Feedwater Treatment

The Permutit Company has just brought out five new bulletins on its feedwater treatment. The first, No. 2118, deals with "Zeo-Karb," a new carbonaceous zeolite, and discusses its applications and operating principles. A second describes and gives specifications on a new rate-of-flow indicator. The third, entitled "Operating Cabinets and Tables," outlines four types of master valve controls for filters and softeners. A fourth, No. 2153, describes a multiport valve arranged for automatic, semi-automatic or manual control, one of which replaces nine gate valves formerly employed on softeners and filters. The fifth deals with the Permutit degasifier, a new development in forced-draft aeration.

High-Temperature Cement

Quigley Company has just brought out a 20-page catalog, H. G. 501, dealing with "Hytempite," a plastic, air-setting high-temperature cement for bonding firebrick, for making monolithic baffles and for quick hot or cold furnace repairs. Various applications are illustrated.

Iron Removal Filters

"Ferec Iron Removal Filters" is the subject of a new technical bulletin released by Wm. B. Scaife and Sons Company. This describes a new type of filter designed to remove iron minerals from water by catalytic filtration. Soluble and insoluble iron, regardless of form, are selectively removed. No regenerating chemicals are required.

"Leak-Loss" Chart

A feature of the new catalog brought out by M. B. Skinner Company is a "leak-loss" chart which embodies graphic information valuable to anyone operating pipe lines. This chart shows how much steam, water, oil or air escapes from various size leaks in pipe, under various pressures. Figures show what these leaks cost at different unit prices and thus one can visualize the losses that can occur from what are often thought to be harmless leaks. Nine different styles of pipe repair clamps for stopping leaks without replacing pipes are shown in this catalog.

Pumps

Single-suction multistage pumps are described in a 36-page illustrated catalog issued by the DeLaval Steam Turbine Company. As distinguished from pumps widely used for feeding high-pressure boilers and other high-pressure service in which the individual impellers are unbalanced axially, necessitating the use of a thrust bearing or some form of hydraulic balancing device, the pump described has a disk subject to discharge pressure upon one side and to an automatically controlled reduced pressure upon the other, with close axial clearance but no contact with the casing. This pump has labyrinth wearing rings to reduce leakage from discharge to suction, a horizontally split casing and solid, one-piece diaphragms between stages.

Stokers

The Johnston & Jennings Company is distributing copies of catalog No. 11, describing features of the Stowe stoker, which keep the fuel bed at an even depth, side to side, and, front to rear, permitting high rates of burning per square foot of grate area. The catalog is complete with illustrations of installations, engineering diagrams, case histories, including heat balances, etc.

Thermit Welding

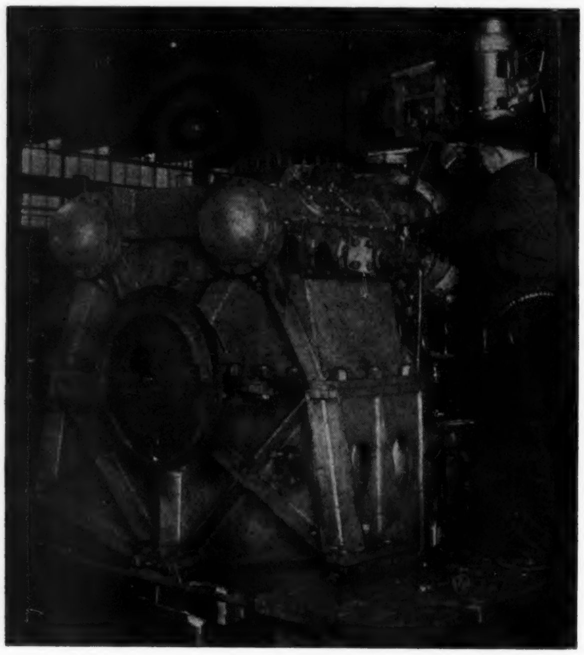
A 34-page booklet describing the thermit welding process and its applications has been issued by the Metal & Thermit Corporation. It gives the history of thermit welding; describes the nature of the thermit reaction, by means of which superheated liquid steel is produced for welding purposes; discusses the physical properties of thermit weld metal; and outlines the methods employed. In addition, the advantages and economies of the process for emergency repairs in various fields are pointed out.

Valve Research

The Edward Valve & Mfg. Company, Inc., has just printed an 8-page bulletin entitled "Just One—of the Big Three." This contains reprints of recent advertisements to valve users discussing methods used in the Edward laboratories for research and production testing of valve materials. Photographs show the equipment and types of tests used in modern high-temperature metals investigation. The aims and results of these tests are described.

High-Pressure Turbine for Locomotive

The accompanying photograph shows one of the two main-drive turbine and gear units of the new steam-



Unit viewed from generator coupling end

electric locomotive just completed by the General Electric Company for the Union Pacific Railroad. Steam is supplied by a forced-circulation boiler operating at 1500 lb per sq in. pressure and 920 F total temperature. The turbine operates condensing.

The new locomotive is said to be capable of doing twice the work of the conventional type of steam locomotive on the same amount of fuel and will go three times as far without stopping for fuel or water.

A.S.M.E. to Meet at New Orleans in February

The 1939 Spring Meeting of the American Society of Mechanical Engineers will be held in New Orleans, La., February 23 to 25. The technical program has been arranged with a view to covering local problems and will include a symposium on burning waste fuels such as wood, paper mill waste, bagasse and peanut shells; also, papers on power for isolated and rural industrial service; corrosion and feedwater treatment; processing methods for cotton and sulphur; and the manufacture of ordnance matériel.

Joint sessions will be held with the Louisiana Engineering Society and an interesting program of plant visits to local industries has been arranged. The many points of local attraction offered by New Orleans, including the Mardi gras festival which occurs at that time, will add to the enjoyment of the meeting. The headquarters and meetings will be at the St. Charles Hotel. The complete program of papers and authors is not yet available but will be announced in the February issue of *Mechanical Engineering*.

EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

	1938 Water Tube		1937 Water Tube		1938 Fire Tube		1937 Fire Tube	
	No.	Sq Ft	No.	Sq Ft	No.	Sq Ft	No.	Sq Ft
Jan.	52	201,151	52	256,368	35	42,752	65	84,889
Feb.	48	185,257	51	198,957	45	55,173	74	89,133
Mar.	58**	238,830**	142	791,168	50	49,039	150	211,733
Apr.	48	195,910	60	322,669	37	52,421	75	69,937
May	60	330,653	113	589,347	61	68,288	83	130,782
June	58	190,242	76	330,524	63	86,975	77	100,585
July	67	271,561	83	350,917	69	98,074	83	101,058
Aug.	56	190,762	68	273,726	53	69,494	109	138,501
Sept.	45	169,241	57	241,186	58	62,794	77	103,024
Oct.	51	191,932	66	259,273	46	48,231	59	60,390
Nov.	55	198,589	41	247,882	38	39,198	46	50,644
Jan. to Nov. Inclusive...	598	2,364,128	809	3,862,017	555	672,439	898	1,140,676
1937—12 mos.			861	4,058,481			941	1,178,805

** Revised

Mechanical Stoker* Sales

	1938 Water Tube		1937 Water Tube		1938 Fire Tube		1937 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	28	9,484	63	25,278	76	10,991	140	21,636
Feb.	36**	12,450**	45	16,591	76**	12,216**	120	20,650
Mar.	54	18,820	80	38,074	52	9,434	179	24,709
Apr.	35	12,698	72	37,185	71	11,058	154	23,064
May	32	10,830	65	26,327	106	15,342	137	21,443
June	28	9,284	49	19,787	166	21,378	186	26,627
July	45	17,449	63**	23,135**	191	24,816	251	34,253
Aug.	35	10,991	58	21,998	269	33,199	394	53,096
Sept.	47	16,250	40	11,359	279	28,780	384	46,893
Oct.	42	15,809	53	17,727	300	44,111	310	39,837
Nov.	(November statistics not yet available)							
Jan to Oct. Inclusive.	382	134,065	588**	237,461**	1,586	211,325	2,255	312,208
1937—12 mos.			659	262,834			2,628	361,346

* Capacity over 300 lb of coal per hour
** Revised.

Pulverizer Sales

	1938 Water Tube			1937 Water Tube			1938 Fire Tube			1937 Fire Tube		
	No. N.†	No. E.†	Cap. Lb Coal/Hr	No. N.†	No. E.†	Cap. Lb Coal/Hr	No. N.†	No. E.†	Cap. Lb Coal/Hr	No. N.†	No. E.†	Cap. Lb Coal/Hr
Jan.	5	—	40,500	35	7	554,900	1	—	1,000	—	2	1,700
Feb.	7	1	38,020	2	6	68,300	—	1	800	—	4	3,600
Mar.	—	2	26,100	59	3	713,440**	—	1	700	1	1	2,000
Apr.	2	2	26,600	24	1	257,100	—	—	—	—	2	1,100
May	5	2	33,690	22	—	276,800	—	—	—	—	—	—
June	7	2	49,440	15	—	99,150	—	—	—	—	—	—
July	3	1	23,000	5	6	44,250	—	—	—	—	—	—
Aug.	8	5	155,390	10	15	215,600	1	—	1,000	—	—	—
Sept.	2	1	58,500	14	3	75,900	—	—	—	2	—	2,500
Oct.	2	—	7,650	10	16	302,450	—	—	—	—	—	—
Nov.	7	2	139,800	7	8	220,000	—	—	—	—	1	1,000
Jan to Nov. Inclusive..	48	18	598,690	203	65	2,819,890**	2	2	3,500	3	10	11,900
1937—12 mos.				214	65	2,924,590				3	10	11,900

† N—New boilers E—Existing boilers.
** Revised.

ADVERTISERS IN THIS ISSUE